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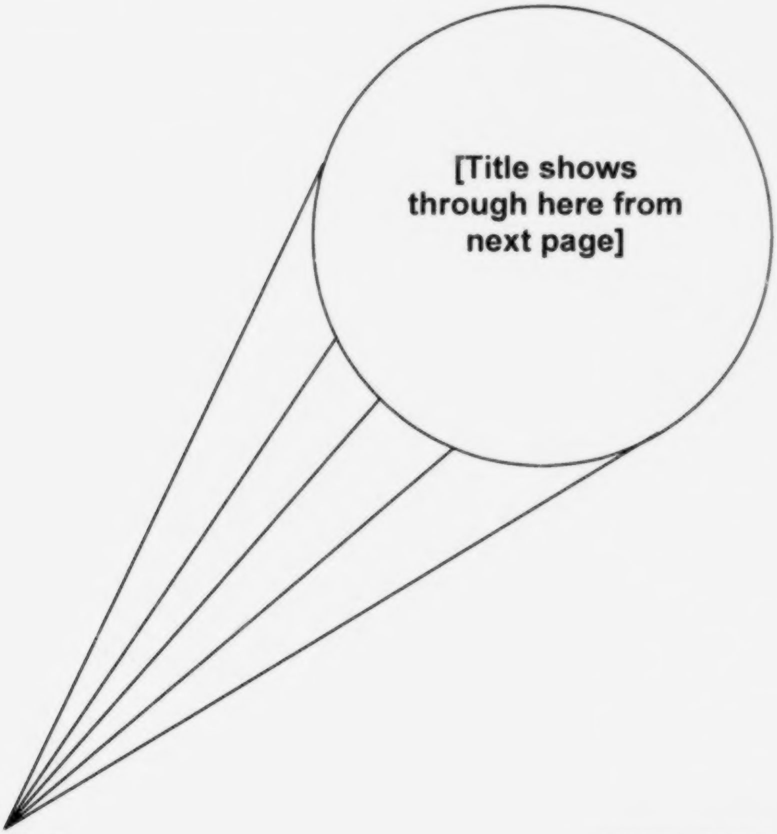
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# Intelligent and Adaptive Interfaces (IAI) for Cognitive Cockpit (CC)

## - Final Report -

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# Abstract

The purpose of this contract was to extend earlier work on goal-tracking interface design principles and methods in order to support adaptive aiding for the CF-18 air domain. A systematic methodology for analysing, designing and building an intelligent help system made use of the CommonKADS knowledge management and engineering methodology, the Explicit Models Design methodology, used in the earlier work, and concepts from the Software Agent Paradigm. Much of the work involved developing templates for representing knowledge contained in a Composite Mission Scenario (CMS) and using those to represent its content. A proposal for managing and engineering help for the CF-18 domain was proposed. Given the development stage of DRDC Toronto's CF-18 simulation, it was not possible to incorporate the work this work into the simulation, however, other alternatives were examined, the most viable of which involved adapting a commercial, off-the-shelf product. Recommendations for future work included refining and extending the proposed methodology, the templates for representing knowledge in the air domain, and concluding that will permit adapting a commercial off-the-shelf simulation to demonstrate intelligent aiding. The last item will help inform the best approach to implementing intelligent aiding for the DRDC simulation, as work on that nears completion.

# Résumé

Le présent contrat a pour objet d'étendre les travaux antérieurs exécutés sur les principes et les méthodes de conception d'une interface permettant de suivre des objectifs afin d'appuyer l'aide adaptative destinée au domaine de vol du CF-18. Une méthodologie systématique d'analyse, de conception et d'élaboration d'un système d'aide intelligent a fait appel à la méthodologie technique et administrative des connaissances CommonKADS, à la méthodologie de conception des modèles explicites, utilisée dans les travaux antérieurs, et à des concepts découlant du paradigme de l'agent logiciel. Une bonne partie des travaux ont porté sur l'élaboration de gabarits visant à représenter les connaissances contenues dans un scénario de mission mixte et à se servir de ceux-ci pour représenter son contenu. Une proposition de conception technique et de gestion d'une aide pour le domaine du CF-18 a été soumise. Compte tenu du stade de développement de la simulation du CF-18 à RDDC Toronto, il n'a pas été possible d'intégrer ces travaux à la simulation; par contre, d'autres alternatives ont été examinées, la plus viable comprenant l'adaptation d'un produit commercial déjà sur le marché. Les recommandations relatives à de futurs travaux comprenaient le raffinement et l'extension de la méthodologie proposée, des gabarits destinés à représenter les connaissances dans le domaine de vol et la conclusion permettant d'adapter une simulation disponible sur le marché pour démontrer l'aide intelligente. Le dernier élément va aider à communiquer la meilleure approche pour mettre en œuvre l'aide intelligente destinées à la simulation de RDDC, les travaux à ce sujet étant bientôt terminés.

## Executive Summary

The purpose of this contract was to extend the intelligent goal-tracking interface design principles and methods from earlier work on the *LOCATE* workspace layout tool to develop and implement an adaptive interface for a Cognitive Cockpit project. Where feasible, the work also sought to use the results of an earlier, co-operative effort with DERA Farnborough, UK, which made progress in generalising the same goal-tracking technology for an emerging goal and plan tracking system of their own. In broader terms, the current effort sought to isolate the intelligent goal-tracking and aiding implications, towards a partially decomposable, pluggable module that would be usable by other software.

More specifically, the current work sought to extend the goal and plan tracking infrastructure from the *LOCATE* workspace layout tool to monitor pilot behaviour in a CF-18 air domain. In the air domain, understanding and representing domain knowledge and multitasking behaviour are crucial. A pilot may be pursuing a number of relatively independent goals at once and may be alternating between sets of activities used to achieve those goals. Further, pilots operate in a context that may require immediate response to unexpected events.

Shortly after the initiation of work on this contract, it was determined that what was needed was a systematic methodology for analysing, designing and building an intelligent help system. Earlier work, using Explicit Models Design, had relied on separating knowledge into various models of task, user and system and the current work required both more extensive model representations, which would include dialogue and world models, and a more comprehensive approach to knowledge-based help systems.

The latter requirement was approached through a review and discussion of the CommonKADS knowledge management and engineering methodology that had emerged from the UK's ESPRIT programme in the 1990's. The former was addressed by developing templates for representing the knowledge contained in a Composite Mission Scenario (CMS) that was chosen as a content focus for this project. Further to that requirement, the templates simultaneously emerged and were used to represent much of the knowledge necessary for the support of an intelligent, adaptive system for the CF-18 domain.

Since both approaches were consistent with much current work on agents, CommonKADS (CK) and Explicit Models Design (EMD) were examined and discussed within an agent view for building intelligent systems. Both were shown to fit nicely within the agent paradigm and specific work on a multi-agent system extension of CommonKADS was discussed.

Multi-tasking issues were addressed in the context of earlier work by the U.S. on the Pilot's Associate and Rotorcraft Associates programmes, and outcomes from those programmes were examined for how they might be useful to the work at DRDC Toronto.

All of the above work on CK, EMD, agents and multi-tasking then was combined into a proposal for managing and engineering help for the CF-18 domain.

As that work was progressing, it became clear that it would not be possible to develop a prototype system, given the stage of development of DRDC Toronto's CF-18 simulation. Although considerable effort had been expended on the simulation, it was clear that certain components, necessary to develop and demonstrate an intelligent, adaptive system, would not be available in time to be accommodated within this contract. Consequently, other alternatives were examined that might

serve as a context for illustrating intelligent aiding while the DRDC simulation was being completed.

Several options were explored including purchasing and using commercial, off-the-shelf (COTS) flight simulators, working with a commercial firm to adapt their software to the CF-18 domain and modifying available, open-source cockpit models. Among those, the option of working with a commercial firm seemed the most viable and discussions were initiated with a principal of one of those firms to develop an agreement to use the source code of their F-18 simulation.

Much of the other effort on the contract involved working with the Composite Mission Scenario (CMS) to develop pseudo-code that could be used to represent requisite knowledge for the air domain and support the adaptive help that would be provided. The CMS consisted of about twenty pages of natural language description and the attempt to formalise the knowledge contained in the CMS was a considerable challenge. A set of templates were developed and used to generate about 80 pages of representations for the content in the CMS document. The templates were modified during application to the task and require further refinement to build a general representational code useful with other scenarios.

Results of the knowledge representation effort pointed to the need for a structured world model that will permit various inter-related elements to be represented. Difficulties in natural language representation are not new and some of the principal ones identified in the selected scenario include: 1) comparative references; 2) time; 3) summary expressions; 4) paraphrases; 5) goal (intent) expressions; 6) relationships among facts, events, activities, propositions, etc.; and, 6) implications.

Future work should refine and extend the proposed comprehensive methodology for analysing, designing and implementing knowledge-based help systems. Similar refinement and extension should be done on the knowledge representation pseudo-code with a view to developing broad capabilities to represent knowledge needed in the problem domain. Decomposing the knowledge into suitable models, useful in monitoring pilot actions and states, should involve both the separation of knowledge and its co-ordination. Finally, work needs to be concluded quickly on an agreement to adapt a commercial off-the-shelf simulation to demonstrate intelligent aiding. Work with that software will help inform the best approach to implementing intelligent aiding within DRDC's CF-18 simulation, as work on it nears completion.

Edwards, J. L. 2004. Intelligent and Adaptive Interface (IAI) for Cognitive Cockpit (CC). AC232, DRDC Toronto CR 2004-127.

# Sommaire

Le présent contrat vise à étendre les principes et les méthodes de conception d'une interface permettant de suivre des objectifs intelligents à partir de travaux antérieurs sur l'outil d'aménagement de l'espace de travail *LOCATE* afin d'élaborer et de mettre en œuvre une interface adaptative pour un projet de poste de pilotage cognitif. Dans la mesure du possible, les travaux ont aussi cherché à utiliser les résultats d'un travail de collaboration précédent avec le DERA Farnborough (R.-U.), qui a fait des progrès en généralisant la même méthodologie de suivi des objectifs pour un nouveau système de suivi de plans et d'objectifs qui lui est propre. En termes plus généraux, les efforts actuels ont cherché à isoler les conséquences d'une aide et d'un suivi des objectifs intelligents sur un module enfichable, partiellement décomposable qui pourrait être utilisé par d'autres logiciels.

Plus précisément, les travaux actuels ont cherché à étendre l'infrastructure de suivi des plans et des objectifs à partir de l'outil d'aménagement de l'espace *LOCATE* pour surveiller le comportement d'un pilote dans le domaine de vol du CF-18. Dans ce domaine de vol, la compréhension et la représentation des connaissances du domaine et du comportement face à des tâches multiples sont cruciales. Un pilote pourrait poursuivre simultanément un certain nombre d'objectifs relativement indépendants et pourrait se déplacer entre des ensembles d'activités pour atteindre ces objectifs. En outre, les pilotes évoluent dans un contexte qui pourrait nécessiter une réaction immédiate à des événements imprévus.

Peu après le début des travaux de ce contrat, on a déterminé qu'on avait besoin d'une méthodologie systématique visant à analyser, à concevoir et à élaborer un système d'aide intelligent. Des travaux antérieurs, faisant appel à la conception de modèles explicites, s'étaient fondés sur la distinction des connaissances en divers modèles de tâches, d'utilisateurs et de systèmes, alors que les travaux actuels nécessitaient des représentations plus poussées de modèles, incluant des modèles de dialogues et de mondes, et une approche plus détaillée face aux systèmes d'aide fondés sur les connaissances.
Cette dernière exigence a été abordée par une revue et une discussion de la méthodologie technique et administrative des connaissances CommonKADS résultant du programme ESPRIT du R.-U. dans les années 1990. La première exigence avait fait l'objet d'une élaboration de gabarits visant à représenter les connaissances figurant dans un scénario de mission mixte qui avait été choisi pour son contenu dans le cadre de ce projet. Outre cette exigence, les gabarits obtenus ont été utilisés pour représenter la plupart des connaissances nécessaires au soutien d'un système intelligent adaptatif pour le domaine du CF-18.

Comme les deux approches étaient compatibles avec beaucoup de travaux actuels sur les agents, on a examiné CommonKADS (CK) et la conception des modèles explicites (EMD), et eu des discussions du point de vue de l'agent en vue d'élaborer des systèmes intelligents. Les deux correspondaient bien au paradigme de l'agent, et des travaux spécifiques sur l'extension d'un système multi-agents de CommonKADS ont fait l'objet de discusisons.

Les questions relatives aux tâches multiples ont été abordées dans le contexte des travaux antérieurs menés par les États-Unis dans le cadre des programmes associés de pilotes et de giravions. Les résultats de ces programmes ont été examinés afin qu'on puisse déterminer dans quelle mesure ils pourraient être utiles aux travaux menés à RDDC Toronto.

Tous les travaux ci-dessus menés sur CK, EMD, les agents et les tâches multiples ont alors été combinés dans une proposition visant à concevoir techniquement et à gérer l'aide pour le domaine du CF-18.

À mesure que les travaux progressaient, il est devenu clair qu'il ne serait pas possible de développer une système prototype, compte tenu du stade de développement de la simulation du CF-18 à RDDC Toronto. Bien que de nombreux efforts aient été consacrés à la simulation, il était clair que certains composants, nécessaires au développement et à la démonstration d'un système adaptatif intelligent ne seraient pas disponibles à temps pour être intégrés au présent contrat. Par conséquent, d'autres alternatives ont été examinées qui pourraient servir de contexte visant à illustrer une aide intelligente pendant que le RDDC compléterait sa simulation.

Plusieurs options ont été explorées, notamment l'achat et l'utilisation de simulateurs disponibles sur le marché, le travail avec une entreprise commerciale pour adapter son logiciel au domaine du CF-18 et la modification des modèles de poste de pilotage d'exploitation libre disponibles. Parmi elles, l'option de travailler avec une entreprise commerciale a semblé la plus viable, et des pourparlers ont été amorcés avec le dirigeant d'une de ces entreprises pour conclure un accord permettant d'utiliser le code source de sa simulation de F-18.
Une bonne partie des autres efforts déployés dans le cadre du contrat avaient trait au travail du scénario de mission mixte et ils visaient à mettre au point un pseudo-code qui pourrait servir à représenter les connaissances préalables sur le domaine de vol et à appuyer l'aide adaptative qui serait fournie. Le scénario de mission mixte comprenait une description de vingt pages en langage naturel, et la tentative de mettre en forme les connaissances figurant dans le scénario a constitué un défi de taille. Un jeu de gabarits a été produit et utilisé pour générer environ 80 pages de représentations de contenu dans le document du scénario. Les gabarits ont été modifiés lors de l'application à la tâche et ils ont dû être raffinés encore plus pour permettre l'élaboration d'un code représentationnel général pouvant être utile à d'autres scénarios.

Les résultats des efforts de représentation des connaissances ont indiqué la nécessité d'un modèle du monde structuré qui permettra à divers éléments inter-reliés d'être représentés. Les difficultés dans la représentation du langage naturel ne sont pas nouvelles, et certaines des difficultés principales relevées dans le scénario retenu comprennent : 1) des références comparatives; 2) le temps; 3) des expressions sommaires; 4) des paraphrases; 5) l'expression des objectifs (intention); 6) les rapports entre les faits, les événements, les activités, les propositions, etc.; et 7) les conséquences.

Pour l'avenir, les travaux devraient raffiner et étendre la méthodologie détaillée proposée pour l'analyse, la conception et la mise en oeuvre de systèmes d'aide fondés sur les connaissances. Un raffinement et une extension similaires devraient porter sur un pseudo-code de représentation des connaissances dans l'optique de développer des capacités élargies pour représenter les connaissances nécessaires dans le domaine des problèmes. La ventilation des connaissances en des modèles appropriés, utile pour surveiller les actions et l'état des pilotes, devrait prévoir la séparation des connaissances de leur coordination. Finalement, les travaux doivent être menés rapidement sur l'accord visant à permettre d'adapter une simulation disponible sur le marché pour démontrer l'aide intelligente. Les travaux sur ce logiciel aideront à déterminer la meilleure approche pour mettre en oeuvre l'aide intelligente dans le cadre de la simulation du CF-18 de RDDC, les travaux à ce sujet étant bientôt terminés.

Edwards, J. L. 2004. Interface adaptative et intelligente (IAI) pour le pilotage cognitif (PC). AC232, DRDC Toronto CR 2004-127.

# Table of Contents

- Abstract i
- Résumé ii
- Executive Summary iii
- Sommaire v
- Table of Contents vi
- Background 1
- Research Approach 2
  - Scope of Work 2
  - Study Objectives 3
- Composite Mission Scenario 4
  - Selecting a Composite Mission Scenario 4
  - Composite Mission Scenario Description 4
- Knowledge Representation, Management and Engineering 6
- The CommonKADS Methodology 8
  - Overview of CommonKADS 8
  - Application of CommonKADS to the CF-18 Help System 9
- Organisation Model 9
- Task Model 10
- Agent Model 11
- Knowledge Model 11
- Communication Model 13
- Design Model 14
  - Applying CommonKADS to the CF-18 Intelligent Aiding System 16
- Creation of Explicit Models 17
  - Overview of Explicit Models Design 17
  - EMD's Contributions to the CF-18 Project 17
- Task Model 17
- System Model 18
- User Model 19
- World Model 20
- Dialogue Model 20
- Plan Recognition 20
- Plan Generation 21
- Feedback 21
- The PACT Approach and Automation Levels 23
- Software Agent Paradigm 24
  - Overview of Agent-Oriented Development 24
  - Agents in CommonKADS 25
  - Agents in Explicit Models Design 26
- Multi-tasking and Conflict Detection 27
  - The Associates Programmes and Plan Goal Graphs 27
  - Multitasking for the CF-18: Help from the Associates and the *LOCATE* Projects 28
  - Conflict Detection 29

Design and Implementation for the CF-18 ........ 30
  Proposed Approach for Managing and Engineering Help ........ 30
Developing a Knowledge Representation Scheme ........ 32
  Templates for Representation Scheme ........ 32
  Knowledge Representation Scheme for the CMS ........ 33
A Context for the Study of Intelligent, Adaptive Aiding ........ 35
  DRDC Toronto's CF-18 Simulation ........ 35
  Alternatives Contexts for Adaptive Aiding ........ 38
Issues and Questions for SME's ........ 40
  Friend-or-Foe Identification ........ 40
  Re-group/Re-task ........ 40
  Formations ........ 41
  Equipment Failure ........ 41
  Presentation of Data ........ 41
  Programming of EGI ........ 41
  Course Detection ........ 42
  Air-to-Air Refuelling ........ 42
Future Work ........ 43
Annexes ........ 46
  Annex 1: SECTION FIVE – COMPOSITE MISSION SCENARIO ........ 48
  Annex 2: KNOWLEDGE REPRESENTATION TEMPLATES AND EXAMPLES ........ 70
  Annex 3: KNOWLEDGE REPRESENTATION IN THE COMPOSITE MISSION SCENARIO ........ 83

# Background

The objective of the proposed Cognitive Cockpit Technology Demonstration Project (DRDC Toronto, 2001a) is to demonstrate the effects of new interface technologies on mission performance, and to develop the human factor guidelines for their development and future procurement (2015-2020) through extensive use of Simulation and Modelling for Acquisition, Rehearsal and Training (SMART) methods.

The project also will develop a facility for specifying and assessing display options for a current procurement activity — the CF-18 Incremental Modernisation Program (IMP). Options for the CF-18 IMP are more modest than those projected for the proposed CC TDP. The Cognitive Cockpit will incorporate dynamic adaptive interfaces for both information display and life support equipment. It will be driven by information about the crew's actions at the interface and by their inferred physiological and psychological states.

Previous efforts supporting work on a Cognitive Cockpit include:
- developing a theoretical basis for enhanced Situation Assessment (SA) technologies;
- constructing a cockpit for a CF-18 Aircraft Crewstation Demonstrator (CF-18 ACD);
- monitoring projects on advanced physiological monitoring;
- learning about CF-18 operations; and,
- designing an intelligent goal-tracking interface.

One of the challenges for this Statement Of Work (SOW) will be extending goal and plan tracking from *LOCATE* (Edwards & Hendy, 2000) for a multitasking environment. Although multitasking can occur in *LOCATE*, it is both simple and rare and to date little attention has been paid to this issue. In the air domain, however, understanding and representing multitasking behaviour are crucial. A pilot may be pursuing a number of relatively independent goals at once and may be alternating between sets of activities used to achieve those goals. Conflict detection will be an added aspect of the goal and plan tracking requirements for the Cognitive Cockpit.

This work will extend the intelligent goal-tracking interface design principles and methods to develop and implement an adaptive interface for the Cognitive Cockpit project. Where feasible, this work will use the results of a co-operative effort with DERA Farnborough, UK, who generalised the goal-tracking technology for an emerging goal and plan tracking system of their own. In broader terms, this effort will isolate the intelligent goal-tracking and aiding implications, towards a partially decomposable, pluggable module usable by other software.

# Research Approach

## Scope of Work

In the current context, the ultimate purpose of an intelligent adaptive interface is to decrease workload and improve situation assessment. The scope of work starts with *LOCATE* (Edwards & Hendy, 2000). *LOCATE* is a workspace layout tool that has a goal and plan tracking interface and an intelligent, adaptive aiding capability. The principles and methods developed there will be extended to an Intelligent Adaptive Interface (IAI) for the Cognitive Cockpit.

First, the contractor will become familiar with the CF-18 ACD's hardware and software components and function, learn about CF-18 mission planning, and identify a composite mission scenarios for demonstration purposes. The contractor will ensure that mission planning and mission tasks are in terms of goals as required by *LOCATE's* goal and plan tracking architecture A starting point for this activity will be the air-to-air (BAE Systems, 2000) and air-to-ground (DRDC Toronto, 2001b) task analyses developed under contract for DCIEM (now, DRDC Toronto).

Second, the contractor will discuss with the Scientific Authority (SA) and Subject Matter Experts (SME) how cockpit elements might be modified to aid pilot workload management and improve situation assessment. A clear advantage for IAI in this domain is that the mission scenarios are procedural (plans already exist). SMEs will help identify areas where procedures are vague and recommend how those might be strengthened.

Third, the contractor will design and implement examples of adaptive intelligent interfaces. Part of the design and implementation will be to explore knowledge-based components for adaptive interface design. For example, CommonKADS, currently in use by the British in their Cognitive Cockpit, will be examined and compared to other knowledge management schemes, such as Perceptual Control Theory and Explicit Models Design. The system will combine knowledge and information about pilot and world states to better infer online pilot intent and goals.

Finally, the contractor will identify the requirements for the intelligent adaptive interface that will be used to aid the pilot during a CF-18 composite mission scenario. This constitutes work in the area of plan recognition. Work will be done on the adaptive capabilities that support the interface, including identification of display adaptations, information content that should be presented, and when and how it should be presented. Also, conditions for task re-allocation will be considered, and how those are related to the goals and plans of the pilot.

The following is an expected list of tasks that the contractor will undertake:

- Program Management

    Program Supervision and Control
    Initial and progress meetings

- Recast mission plans and mission tasks to be compatible with goal and plan tracking

    Become familiar with CF-18 ACD, and relevant CF-18 mission scenarios

Develop a composite scenario for demonstrating the IAI
Make required changes to the goals and plans for the composite scenario

- Knowledge Management

  Investigate knowledge management and engineering formats
  Recommend a knowledge management framework for the IAI system

- Requirements for Proposed CC TDP IAI

  Identify adaptive capabilities for a goal and plan tracking infrastructure
  Identify multisource and multimodal information
  Identify pilot and external states needed to infer online pilot intent
  Determine software platform for development

- Modified Cognitive Cockpit Architecture

  Propose an architecture showing modifications to the proposed CC TDP for supporting the IAI

- IAI Demonstration

  Design, implement, and demonstrate examples of adaptive displays and controls
  Build prototype that demonstrates tracking multiple activities

## Study Objectives

The objectives of this contract are:

1. Provide a statement of requirements for a Cognitive Cockpit goal and plan tracking component
2. Develop an analysis of the causal structure of mission plans for composite mission scenario
3. Provide a statement of adaptive capabilities in the context of the mission scenario
4. Supply any prototype examples developed to illustrate aspects of the IAI

# Composite Mission Scenario

## Selecting a Composite Mission Scenario

The first task addressed in the contract was to select a Composite Mission Scenario (CMS) that would serve as the context for the work. After discussions with the Scientific Authority, a CMS was chosen from a report entitled, CF188 APG-65 Radar Human Factors Engineering Study Mission Analysis Report prepared for DRDC Canada by Bae Systems Canada Inc.

The objective of the CF188 APG-65 project is to develop a distributed simulation for the evaluation of the APG-65 Radar operator interface. In section 5.0 of that report a mission scenario is presented whose purpose is "to provide APG-65 Radar Project team members with a baseline document that describes the key elements, implied requirements and essential system functions." (p. 5.1)

The scenario was chosen as a way of illustrating representational issues within the current project, whose purpose is to lay a foundation for the design and implementation of an intelligent, adaptive interface for the air domain. The entire section 5.0 of the BAE report, including a general description and aim of the scenario as well as the scenario itself, appears in Annex 1. A brief overview of the CMS will serve as an introduction.

## Composite Mission Scenario Description

The specific aim of the selected composite mission scenario (CMS) is to portray the planning and execution of a CF-18 air-to-air operation which[1]:

- focuses on the tactical application of air operations solely – not the overarching strategic objectives;
- integrates the air power capabilities of several different nations and services;
- exploits the capabilities and roles of the CF-18 while considering its limitations;
- incorporates an all weather/night aspect to the overall mission profile/taskings;
- is based on current realistic CF-18 operational training and aircrew proficiency levels;
- necessitates positive identification in the air when called for by scenario Rules Of Engagement (ROE);
- uses a single ATO, easily disseminated by a Tactical Air Operations Centre (TAOC); and
- relies on comprehensive, timely, accurate and current intelligence which is air focused.

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[1] In describing the composite mission scenario (CMS), elements of Annex 1 are repeated here.

A variety of events are described that serve as a background context for the CMS. Those events constitute a current crisis that results in a request to Canada to deploy armed forces in support of operations aimed at re-establishing Zardian rule of law on its northern provinces and to assist, as may be required, in the eviction of all X-Y-E armed forces and extremist elements.

In support of the air campaign, Canada has provided four CF-18's and those have been tasked as follows:

- to conduct a Combined Allied Military Air Operation (CAMAO) Route Sweep for a package of 8 UK Tornado GR-1 ground attack aircraft (their task is interdiction of a re-supply choke point on the island of Y);
- to rendezvous (RV) with a Royal Air Force (RAF) VC-10 Air-to-Air Refuelling (AAR) Tanker post Sweep mission;
- to re-commit to new tasking as High Value Airborne Asset (HVAA) protection; that is, NATO E-3 Airborne Warning and Control System (AWACS) – to include, Mixed Fighter Force Operations (MFFOs) with Royal Netherlands Air Force (RNAF) F-16 aircraft;
- to RV with a RAF VC-10 AAR, post HVAA mission;
- to re-commit to new tasking to establish (base defence) CAP/Fighter Area of Operational Responsibility (FAOR); and
- recover to a deployment base/aerodrome.

Threats include both air-to-air and surface-to-air possibilities.

Key elements of the mission include:

- Start and Taxi
- Take-Off and Climb
- Transit to Tactical Rendezvous Point
- Route Sweep
- Air-to-Air Refuelling (DAY, VMC)
- High Value Airborne Asset Protection
- Air-to-Air Refuelling (Night, IMC)
- Fighter Area of Operational Responsibility
- Recovery to Operating Base

# Knowledge Representation, Management and Engineering

In order to provide a basis for intelligent aiding for the CF-18 environment, it will be necessary for the system to understand what the pilot is doing, to have a representation of the mission goals and to track the pilot's execution of plans to achieve those goals.

A similar procedure has been used in recent work on the *LOCATE* workspace layout design tool (W7711-03-7853). There, each interface action by a user is tracked, the user's goals are inferred and the plans the user is employing to achieve those goals constructed.

To have true intelligence and adaptiveness, a system must "understand": 1) what users are doing; 2) the knowledge and attributes of those users; and, 3) its own features and capabilities that may be helpful to users in a variety of circumstances. To extend that understanding in complex situations like that of a CF-18, it must have the ability to reason about information contained in its various knowledge sources and be able to use the results of that reasoning to provide effective help.

As with the *LOCATE* tool, the intelligent aiding system must support adaptiveness during the performance of the task, in the current case through intelligent aiding for pilots as they execute their mission. Unlike *LOCATE*, the system must "understand" many external events encountered during that mission and accommodate them in building a representation of what is happening. The uncertainty that inevitably occurs under circumstances where one individual is attempting to understand the goals (motives) of another is magnified in such circumstances since machine capabilities are far less robust and accurate. Still, it is possible to achieve useful representations given that much of a pilot's mission is "scripted."

One challenge for an intelligent, adaptive system is to maintain a common plan for itself and a user, as it infers what plan likely is underway. An approach that can help support the establishment and maintenance of a common plan is an explicit models representation of task, system and user (Edwards 1990; Edwards, 1994; Edwards & Hendy, 2000; Edwards and Hendy 1992; Edwards and Mason 1988). Those models are in use in the *LOCATE* tool and will be part of the first steps in bringing adaptive aiding to the CF-18 environment. Parcelling knowledge into the various models provides a manageable way of understanding the roles and activities of the pilot and the system and the part they play in the task at hand and in the overall mission.

Adaptiveness emerges as a system interacts with a particular user and builds representations for what that user knows, including: information provided directly by the user; information contained in the help it offers to the user; and, information about the current goals and plans being pursued.

Although the approach of explicit modelling has been useful in designing and building the *LOCATE* tool, there are elements in a critical mission environment, as is the case with this CF-18 project, that go well beyond what has been implemented in *LOCATE*. Additional models that are either implicit or rudimentary in *LOCATE* necessarily need to be elaborated in the CF–18 work. Two such models are those of the world, to help build a context for the pilot's actions, and the dialogue, to help understand and control, in precise ways, the information flow between the pilot and system and among the software agents that make up the system itself. Building a world model that takes advantage of the many things that can happen in the context of a mission is not a simple matter and much of the content of the work done in this contract focuses on providing direction to that task.

Before addressing the knowledge representation task, however, the more general question of a global methodology for the analysis, design and implementation of an intelligent and adaptive aiding system for the CF-18 environment will be addressed. Two approaches will be discussed in some detail: 1) a knowledge management and engineering approach known as CommonKADS, developed as part of work in the 1990's in the European ESPRIT programme; and, 2) Explicit Models Design, briefly described above. A revised methodology combining those two approaches is then offered as a guide to the systematic analysis, design and implementation of an intelligent aiding component for the CF-18 environment.

Following the development of the global methodological approach, representational forms for the selected CMS for this project are addressed, templates for representational forms are offered and a detailed representation of the CMS is presented. This last exercise should give an indication of how to proceed in developing representational forms that can support effective inferences about the CF-18 task, the pilot, the intelligent support system, the dialogue between the pilot and the system, and among system agents, and the relevant elements of the world that exists outside the pilot and system but which influence their behaviour.

# The CommonKADS Methodology

## Overview of CommonKADS

"Intelligent" software, such as that required for a truly adaptive help system, is built using what are called **knowledge-based systems** (KBS), which imitate human reasoning. Such systems are composed typically of formal representations of knowledge about a particular domain and a mechanism that enables the system to "reason" about that knowledge through the application of inferences. This overview section examines the CommonKADS approach (Schreiber, Akkermans, Anjewierden, de Hoog, Shadbolt, Van de Velde & Wielinga, 2000) to analysing and designing *knowledge-based systems* and the role of that approach in a CF-18 help system. Elaborating that approach represents the principal extension in this contract of work begun in earlier work with the UK to generalise the goal and plan tracking work of *LOCATE* to the air-domain. Along with Explicit Models Design, discussed in detail later in this report, it represents an evolving methodology for a comprehensive approach to the analysis, design and implementation of knowledge-based help systems.

The CommonKADS methodology provides a framework designed specifically for developing knowledge systems. CommonKADS has several strengths that make it a suitable choice for use in developing an intelligent, adaptive system for helping users. A key advantage is that it guides developers through a systematic process intended to settle all issues related to the design of the software before any code has been written. Such a process substantially reduces the likelihood that developers will have to revise the design once implementation is underway. Other benefits of the approach include improved maintainability, reliability and reusability of software components over conventional less comprehensive and *ad hoc* approaches. Those benefits will be discussed in greater detail in subsequent sections, but first an overview of the CommonKADS methodology is in order.

CommonKADS and its antecedent, the KADS (Knowledge Acquisition and Design Structuring) methodology, are the products of a collaboration of European researchers in the 1980's and 1990's and funded as a series of projects under the ESPRIT programme. The methodology provides a systematic approach to analysing organisational needs, identifying opportunities for the deployment of knowledge systems and ultimately designing an implementation of the requisite system.

The CommonKADS methodology provides a step-by-step approach to analysing a given problem domain. Questions are posed at each stage through standard "worksheets," which provide a systematic tool for documenting both questions and answers concerning key issues. Individual, numbered guidelines are also offered to assist with the construction of more detailed components of the models.

An important term often used to refer to domains that could benefit from intelligent system design is **knowledge-intensive.** More specifically, the term is used to describe tasks that would benefit from an implementation that features a formalised representation of knowledge and an associated inference mechanism. Many, if not most, tasks carried out in software design do not require such treatment, and can be addressed with traditional software implementation approaches. For example, most help systems, even for highly complex software, typically would not benefit from a knowledge-based approach since they simply involve displaying simple help material when the user requests it. On the other hand, a *knowledge-intensive* help system with inference capabilities would benefit from methodologies such as CommonKADS because of the tools they provide for knowledge analysis, design and implementation that cannot be found in standard programming approaches. Examples of *knowledge-intensive* tasks include those that mimic human activities, such as diagnosis, planning and design.

## Application of CommonKADS to the CF-18 Help System

Since CommonKADS was developed specifically for guiding the analysis, design and implementation of knowledge-based systems, it is very well suited to producing such a system to assist users in the CF-18 context. As the first theoretical component contributing to the help system framework, it provides a solid foundation on which to build.

The process of applying CommonKADS in order to build a help system will involve the specification of the following six models:

- Organisation Model;
- Task Model;
- Agent Model;
- Knowledge Model;
- Communication Model;
- Design Model.

### Organisation Model

The Organisation Model is assembled during the initial feasibility and assessment phase of a CommonKADS analysis. The primary emphasis of that phase is to examine organisational or business processes that could benefit from the implementation of a knowledge system. Coupled with that is the subsequent feasibility analysis that weighs the costs associated with such an implementation against the projected benefits. Thus, a system must be sufficiently *knowledge-intensive* to warrant its implementation using CommonKADS. Worksheet questions help to identify the structure of the organisation, relevant processes, people and resources involved and knowledge assets required.

Organisationally, it has already been determined that the addition of a knowledge-based system for assisting CF-18 pilots would be beneficial and feasible. As a consequence, it is unlikely that an organisational analysis, if conducted, will figure as prominently as it would in other projects.

However, it should be noted that the authors of the CommonKADS approach emphasise the importance of an initial phase in which a systematic analysis of the organisation is conducted. They point to situations where applying the methodology has revealed needs for a knowledge system that are substantially different from those projected at the outset of analysis. The use of CommonKADS to design an adaptive interface for helping pilots likely would not feature a detailed examination of organisational issues, however, an abbreviated analysis of the organisational structure within which CF-18 missions reside could offer insights into how the knowledge system should be developed. Some aspects of that context often are provided within Composite Mission Scenarios (CMS's) themselves. The one chosen for the current work is no exception.

## Task Model

The Task Model in CommonKADS is created primarily as part of the organisational analysis and feasibility assessment and focuses on high-level tasks and goals of agents in the system. Tasks are examined with a view to identifying those that are sufficiently *knowledge-intensive* that they would benefit from the implementation of a knowledge-based system.

To create an explicit representation, tasks and sub-tasks are represented using flow diagrams from the Unified Modelling Language (UML). UML is the standard technique in CommonKADS for schematically depicting activity, state and class diagrams that can represent a wide range of concepts such as data flow, inferences and task structures.

Construction of the Task Model involves the creation of a task hierarchy, in which tasks are decomposed into sub-tasks. Questions posed during Task Model creation relate to constituent sub-tasks, the agents and objects involved, the timing of the task and knowledge required for performing it. That information can then be referred to later during knowledge model construction.

The CommonKADS approach does not specify the extent to which tasks are to be decomposed into sub-tasks, as that is project-dependent. For a given project, practical boundaries must be established during the design phase to minimise the collection of unnecessary material. For example, the CF-18 task of establishing and executing a mission does not require the inclusion of a representation of strategic goals and plans in order to be conducted successfully. During the Task Model phase of the CommonKADS analysis, it is not necessary to address that level of detail since the intention is to develop general specifications for agent responsibilities and knowledge requirements.

In contrast, the Task Model in Explicit Models Design allows developers not only to focus on the high-level goals of the task but also to look beyond those goals in either direction and represent tasks at all levels. For more detail, refer to the "Creation of Explicit Models" section.

In the case of the CF-18 mission, the focus of the CommonKADS Task Model construction would be the high-level tasks of the pilot. That would include elements such as those identified above: start and taxi; take-off and climb; transit to tactical rendezvous point; route sweep; etc.

Although CommonKADS specifies that UML be used for representing task hierarchies, there are limitations to what that language currently is able to express and, consequently, it is recommended that an alternative complement to UML be considered for use in the implementation of help systems for certain applications. UML's limitations relate to the representation of temporal constraints, such as concurrency of tasks and their performance in real-time. In designing help systems for applications for which precise timings of events is critical, it is recommended that other languages be explored for their potential contribution in this area. One candidate is the IDEF3 language, which might be used for the graphical representation of tasks and sub-tasks. More investigation is needed of IDEF3, however, before its adequacy for the CF-18 domain can be determined.

In contrast to the Organisation Model, the Task Model has greater potential for providing insights into how to proceed with design of the help system. A formal statement of tasks and sub-tasks will help to identify responsibilities that can be carried out by software agents. Such tasks include:

- monitoring the user's activities;
- inferring the user's immediate goals and broader plans;
- generating system plans to assist the user in the most effective way given current circumstances.

Identification of those tasks should be performed in consultation with subject-matter experts in the air domain.

It should be noted that the creation of a task hierarchy is fundamental to Explicit Models Design as well and will be discussed further in that section.

## Agent Model

Like the two models already described, the Agent Model is developed during the initial feasibility phase. It is used to identify the participants in the itemised tasks so that their responsibilities can be incorporated into any resulting knowledge system. That process also assists with identifying expert sources of knowledge that can be useful in supplying information and providing rules for the knowledge base.

Construction of the Agent Model involves examining the tasks in which each agent is involved, the other agents with which it communicates and knowledge that is required to complete its tasks.

Networks of software agents increasingly are used as a new paradigm in the design and construction of intelligent systems. Their use in the support of intelligent aiding for CF-18 pilots will be worth closer examination. At minimum, the pilot and the intelligent system can be formulated as agents within the overall "mission system." An analysis of the opportunities for decomposing the computer system into specialised agents would be a worthwhile exercise in future work.

## Knowledge Model

The Knowledge Model contains a detailed enumeration of all knowledge required to perform the tasks that the system will be performing. Thus, most of the architecture of the knowledge system is designed during the formulation of that model. The Knowledge Model is a specification of requirements that is independent of the implementation approach. Thus, when a "rule" is specified, it is not a rule as it would be entered into a particular knowledge-based system, but it is rather a rule as it might be characterised by a human expert, without concern for adapting it to the needs of a particular implementation environment, thereby allowing an extra level of freedom for the designer.

The Knowledge Model is subdivided into three categories: "domain," "inference" and "task" knowledge. **Domain knowledge** contains all of the data used by the application, which, in object-oriented terminology, would correspond to the class definitions and object instances. CommonKADS does not follow the object-oriented paradigm, however, using the term "concept" instead of "class." Like classes, concepts have attributes and those attributes can be assigned values. Unlike classes, however, concepts do not have encapsulated methods but, instead, the methods are contained in the other two components of the knowledge model. Concepts can have subtype and supertype relationships to other concepts, thereby enabling the traditional object-oriented notions of inheritance and subsumption.

In the case of CF-18 help system, the domain knowledge would include knowledge relating to the capabilities and functions of the software, including user and system tasks described in the Task Model and, beyond that, the domain of missions, SOPs and information about real-time changes taking place in the world in which the mission takes place.

The second component of the Knowledge Model is the **inference knowledge**, which is a collection of methods that act on the domain knowledge. Thus, they are not exclusively functions that make inferences in the traditional knowledge system sense, but can include any method that acts on domain knowledge. Methods are separated from objects in CommonKADS to allow them to be individually reusable.

CommonKADS provides a catalogue of inference templates, an approach that has multiple advantages. Creating methods that can be applied generally allows them to be reused readily in other applications. Because they have been applied in other situations, they come pre-tested and therefore contribute to the overall reliability of the knowledge system. Standard inferences include: classify, compare, evaluate and predict.

Examples of inference knowledge in the help system would include methods for inferring goals from actions or hypothesising a plan based on a user's actions.

The final component of the Knowledge Model is **task knowledge**, comprising a set of higher-level methods that implement a hierarchy of tasks and sub-tasks. At the lowest level, the sub-tasks make use of methods in the underlying inference knowledge layer, which in turn operate on the domain knowledge.

*Task knowledge* in the CF-18 context would include a representation of the full task hierarchy derived in the specification of the EMD Task Model (see the "Explicit Models Design" section).

As with the inference knowledge, there are templates available for task knowledge and they share the same benefits of reusability and reliability. Templates that are provided include those for planning, scheduling and monitoring, all of which would be useful in the help system. Planning and scheduling are tasks required for **plan generation** and monitoring is performed in association with **plan recognition** (see the section on Explicit Models, below, for more detail on plan generation and recognition).

Knowledge modelling in any context typically involves the creation of an ontology, and CommonKADS is no exception. Ontologies are formally specified frameworks within which knowledge can be represented. A chief goal in producing an ontology is to identify patterns in the knowledge and exploit those to produce a highly organised and concise specification. One of the main motivations for generating an ontology for a particular domain is to allow its reuse in other applications.

In CommonKADS, an ontology is referred to as a domain schema, which is a formal statement of the structure of all concepts, relations and rules for a particular domain. Maintained separately from the domain schema is the knowledge base, which is a database of specific instances of the concepts, relations and rules. That separation mirrors the distinction in object-oriented analysis between class definitions and instantiated objects.

CommonKADS does not provide much guidance for ontology construction and lacks concrete examples to illustrate how ontologies should be structured. Again, the ontology description methods from the IDEF standards are candidates that should be examined, specifically, "IDEF5."

In order to describe fully the Knowledge Model for the help system, it will be necessary to design the content of the various Explicit Models first. The section on "Explicit Models Design" describes how those models are constructed.

## Communication Model

The purpose of the communication model is to describe communication that must occur among agents in the knowledge system. That can include dialogue that is both between the user and system agents, and between individual software agents.

Communication is broken down using a transaction model. For each pair of agents that must interact, a communication plan is constructed (often represented using UML) that outlines the flow of information and decisions affecting that flow. That is decomposed further into a detailed itemisation of individual transactions, where each one represents a message sent from one agent to another. Each transaction is described in terms of the agents involved, the content of the message and knowledge objects exchanged.

Standard patterns of communication are described in CommonKADS, such as the straightforward "Ask" and the associated "Reply," or slightly more complex exchanges such as, "Require," which can have "Agree" or "Reject" as responses. A library is offered for those and other standard modes of communication.

One type of user-system interaction in the help system will involve the presentation of information by the system and possible acknowledgement from the user. (In situations where it would be disruptive to the user to provide explicit feedback, the system will infer through indirect means that the user has received the information.) In addition to that system-initiated communication, users will also be able to request information from the system, which necessitates a second form of dialogue. Interaction could also consist of a clarification dialogue between user and system agents whereby the system would seek information when the user's current intentions are ambiguous, but care must be taken to avoid unnecessary requests for communication with the user. Guidelines specifying the nature of such communication could be a useful by-product of the Communication Model.

The Communication Model also describes dialogue that occurs among system agents, which will be important in the help system to maintain co-ordination among semi-autonomous entities. Agent interaction in the Communication Model is revisited in the "Software Agent Paradigm" section below.

## Design Model

The Design Model examines hardware and software issues related to the construction of the knowledge system. The aim is to take the implementation-independent specifications from the Knowledge and Communication Models and develop a detailed design for constructing the software application, and in the process preserve the structure of those models. That preservation of structure is achieved by coding the software so that the formal specification of the Knowledge Model can be read in directly to the knowledge system. That approach simplifies future refinement and maintenance of the models allowing changes to the formal specification of the knowledge model to be accommodated without the need for re-coding. Further, it facilitates reuse of the components within the models by isolating them from implementation details.

The first step in the design process is the specification of the system architecture, which is largely predefined in the CommonKADS methodology. Sommerville (1995) recommends that system architecture descriptions include three components:

- decomposition of the system into subsystems;
- overall control regimen;
- decomposition of subsystems into software modules.

Those components are specified in CommonKADS through the use of the Model-View-Controller (MVC) paradigm, originally developed for use in SmallTalk-80. In that approach, the Application Model contains the rules, inference functions, and knowledge bases that are responsible for the main functionality of the application. The Views subsystem provides external views of the data in the application model, which can be in the form of a user-interface or can also involve the presentation of information to an external software system. The Controller handles the processing of events, the triggering of tasks and inferences, and the responsibilities of the Communication Model.

Although the MVC model was originally developed for use in an object-oriented environment (SmallTalk), it does not rely on properties of that paradigm and is therefore equally suitable for use with variants of object-oriented approaches, such as CommonKADS.

The next design step is identifying the target software and hardware platforms. It is recommended that CommonKADS systems be implemented in an object-oriented (O-O) environment, despite the fact that the methodology does not adhere to the O-O approach of encapsulating methods within objects. The required separation between objects and methods can be achieved within an O-O framework by creating separate objects for each. The O-O approach is recommended because most modern environments adhere to that paradigm and most developers are familiar with it. Also, necessary capabilities such as message-passing and multi-threading are typically supported in O-O systems.

Some suggested languages for implementing CommonKADS systems are Prolog and Java, but that is not to the exclusion of other possible environments. Examples of Prolog implementations are offered in Schreiber et al. (2000) and source code for those examples is provided on the CommonKADS web site at www.commonkads.uva.nl.

Prolog has the advantages of extensive inference capabilities and support for the declarative representation of knowledge. A key drawback to that language is its weak support for the object typing that would normally be available in a fully object-oriented environment. That can be addressed with additional coding, and the example on the CommonKADS web site demonstrates how that can be accomplished in Prolog.

Java has full O-O typing facilities and also wide platform support. With the addition of the Java Expert System Shell (JESS), a full inference engine is also available, as is support for declarative knowledge specification. Lacking are examples and source code for CommonKADS implementations in Java, but such code could be modelled on available Prolog examples. If a language other than Prolog is used in the help system, some work will be required to adapt the available CommonKADS code.

The tightest integration could be accomplished by implementing the help system in C++ and making use of an Intelligent Rules Element, similar to the one in the development environment used in building of *LOCATE*. That would offer the necessary dual platform support, O-O typing facilities, inference engine and declarative knowledge specification. As with Java, implementation of the CommonKADS capabilities would need to be modelled on available Prolog examples. A drawback to reliance on the Intelligent Rules Element is that it lacks the wide deployment base that, say, Java enjoys. That could hamper the reusability of help system code in other applications.

Once an implementation environment has been selected, the final step in constructing the Design Model is to create a detailed plan for implementation of the Application Model, Views and Controller, as well as the tasks, inferences and domain knowledge within the Knowledge Model. Many details of the plan are dependent on the chosen environment.

CommonKADS also includes guidelines on project management that are designed to accommodate the unique needs associated with knowledge projects. The development of a project is divided into phases, each encompassing the construction of one of the major CommonKADS models. A cyclical four-step process is recommended, where each repetition produces a more refined version than the last. The first step in the cycle involves establishing objectives for the current phase. The next step seeks to assess risks in the project, such as a lack of available expert consultants, which could affect the quality of the knowledge system. The third step is to produce a detailed plan for the current phase taking into account identified objectives and risks. Last, the development work is monitored and evaluated by the project manager and the results of that stage are fed into the beginning of the next phase in the cycle.

## Applying CommonKADS to the CF-18 Intelligent Aiding System

This section presents a brief summary of the relationships between components currently implemented in *LOCATE's* help system and the CommonKADS methodology, as a way of considering how they might generalise to the CF-18 domain.

The data in the Task, User and System Models would serve as guides for how to represent the domain knowledge in the Knowledge Model. Specifically, knowledge from *LOCATE's* Task Model would include equivalences between actions and goals as well as a hierarchical representation of high-level goals decomposed into constituent subgoals and their associated primitive actions. Knowledge in the User Model would consist of user preferences, information about the user's awareness and capabilities as well as a history of interface activity.

Methods that operate on that domain knowledge would be contained in the inference and task knowledge components of the model. Inference knowledge would encompass methods for deriving primitive user and system support goals[2] from associated interface actions as well as methods that operate in support of the task knowledge. Inferences that operate on the data in the Task, User and System Models would take the form of inference knowledge. Tasks associated with monitoring the user, providing help, recognising users' high-level goals[3] and plans and generating system plans would be incorporated as task knowledge.

The Dialogue Model, which is currently undeveloped in *LOCATE*, closely mirrors the Communication Model in CommonKADS.

A key advantage to applying the CommonKADS methodology to the CF-18 help system is that it is in no way inconsistent or incompatible with the Explicit Models approach that is currently in use in *LOCATE*. In fact, CommonKADS has the potential to enhance the generalisation of *LOCATE's* help system to many other applications through its implementation-independent specification of tasks, inferences and domain knowledge.

Furthermore, once an ontology has been specified for the knowledge system domain and support routines have been written to implement the CommonKADS framework, those components will be in large part reusable, dramatically reducing the work required to deploy the same techniques in another application.

CommonKADS can also aid in help system generalisation through its modularity, permitting those components that are specific to *LOCATE* to be maintained separately from those that are more broadly applicable. Thus, CommonKADS can provide the help system with greater formalisation and compartmentalisation, resulting in improved reliability, maintainability and reusability of system components. All of those characteristics are particularly desirable for the specification of generalised help system implementation guidelines.

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[2] "Primitive goals" are defined here as those goals that are directly associated with actions in the interface. For example, the action of clicking the mouse on an object in *LOCATE's* workspace is associated with the primitive goal (intent): "To select an object."

[3] "High-level goals" are those that can be decomposed into a series of one or more primitive goals. High-level goals may also be made up of high-level subgoals, which in turn are composed of primitive goals.

# Creation of Explicit Models

## Overview of Explicit Models Design

Explicit Models Design (EMD) (Edwards, 1990; Edwards, 1994; Edwards and Hendy, 2000) is an evolving development approach that seeks to make explicit the knowledge required by intelligent software systems. The approach compartmentalises software knowledge into five distinct, interacting models:

- **Task Model**, containing knowledge (beliefs) about tasks being performed;
- **User Model**, comprised of knowledge (beliefs) relating to the user's abilities, needs and preferences;
- **System Model**, consisting of the system's knowledge (beliefs) about itself and its abilities;
- **Dialogue Model**, containing knowledge (beliefs) related to communication among human and software agents;
- **World Model**, representing knowledge (beliefs) of the world relevant to the purpose of the software.

The resulting modular organisation offers a rich set of possible approaches for a system to assist a user. Challenges for EMD lie in how to decompose knowledge into the various models and how to co-ordinate the knowledge among the models to build effective support systems.

Plan recognition and plan generation are two additional processes that operate within the EMD framework to enhance the software's ability to support the user. Plan recognition seeks to establish the current goals of the user in the context of a larger plan. Plan generation is used by the system to develop strategies to accomplish its goals.

## EMD's Contributions to the CF-18 Project

Within the CF-18 project, EMD offers a means of subdividing the content of the CommonKADS Knowledge Model into components. Specification of all models must be done in consultation with subject-matter experts.

### Task Model

The Task Model contains knowledge relating to the tasks being performed by the user, represented as a hierarchy of actions, goals and plans. At the lowest levels of the hierarchy are primitive interface **actions**, such as button clicks and menu selections. EMD recognises that each deliberate interface *action* carried out by a user is in support of a particular **goal** and that actions may be expressed in the terminology of such *goals*. For example, if a user clicks on an "OK" button, the system can infer that the user's *goal* was, "to click the 'OK' button." While the system can easily infer that low-level *goal* from the simple act of clicking an OK button, it is typically much more difficult to establish a higher-level purpose unless additional *actions* are observed. That process is described in the "Plan Recognition" section below.

Above the primitive actions and their associated low-level goals in the hierarchy are **higher-level goals**, which can be achieved only by satisfying one or more primitive goals. Higher-level goals are typically associated with what are commonly known as **tasks**. For example, in the CF-18 mission system, such goals could include, "to reduce altitude to 10,000 feet," or, at a higher level, the goal (task) would be, "to complete the mission."

A path from a terminal node of the tree up to a higher-level goal constitutes a **plan** for accomplishing that goal, and there can be many possible plans for satisfying a given high-level goal. Plan recognition enables the system to determine which of those plans a user is pursuing (see "Plan Recognition" below) and plan generation (see the "Plan Generation" section) permits the system to select a course of action from its available plans, or to recommend a series of actions for the user to satisfy an inferred high-level goal.

The tracking of user interface actions and inference of associated goals provides the system with a basis for understanding what a user is trying to accomplish and for helping that user in ways that are both relevant and useful. The system's ability to deduce user goals would be an essential part of any knowledge system for CF-18 pilot support and EMD provides effective methods for designing such a system.

For the user, plan generation has to do not only with the performance of a task but also with the context in which that task takes place. In part, that means knowledge of system support capabilities, which help determine a course of action. Plan recognition deals with understanding the system's intentions in offering support or with those task-related actions the user allocated to the system at some earlier time.

The EMD Task Model is constructed by extending the CK Task Model goal analysis. While the CK Task Model serves as an effective starting point for a high-level organisational analysis, it does not offer a sufficient degree of low-level detail for implementation of an intelligent, adaptive interface. The EMD Task Model adds that level of detail to the modelling process.

## System Model

The System Model is composed of the system's knowledge about itself, its abilities and the means by which it can assist users. Like the Task Model, the System Model also contains a goal hierarchy, describing the tasks, goals and plans that the system can carry out in support of the user. Those goals are characterised as **system support goals**. Within the CF-18 help system, multiple agents may be a choice in design, thereby requiring a more complex decomposition and distribution of knowledge. Where multiple system agents are involved, the System Model will be partitioned to store a goal hierarchy for each agent.

The System Model task hierarchy will include high-level goals, such as, "to assist the pilot," which would be decomposed into sub-goals, such as those associated with assuming control of sub-systems it had been assigned, monitoring mission status and helping the pilot to complete the mission tasks .

The level of assistance provided by the system is determined by the automation level, specified as part of a **contract** between the user and system. Users may request any of six levels of assistance ranging from no automation to a fully automated and autonomous help system. For more information, see "The PACT Approach and Automation Levels" section.

## User Model

The User Model is comprised of knowledge about the user's (pilot's) abilities, needs and preferences. That information is obtained in three ways:

- from information volunteered by the pilot;
- from the results of system requests of the pilot;
- from system monitoring of pilot activities.

It is worth noting that the system should be able to identify a particular user so that it can maintain a unique profile for each user. Unless that can be done, the system is reduced to providing information that is often too general, repetitive or useless.

Information volunteered by a user often occurs in the context of specifying options and preferences to the system. It is important that pilots be able to specify preferences in order to facilitate efficient functioning of the software, and that is especially useful in domains such as the CF-18 in which pilots can experience high cognitive workloads.

There are several ways in which systems can construct user models by explicitly asking questions of a pilot. For example, if the system has determined which task a pilot is pursuing, it could enquire whether assistance is needed in carrying out that task. The system also might ask if the pilot is aware of alternative plans for accomplishing a task. Finally, if the system cannot determine a pilot's current plan, it may seek clarification on the user's intentions. All of these interventions by the system must be weighed very carefully against other, at times, much higher priority demands on the pilot's time. Even when the pilot has time, the system must not be seen as a distraction or to be asking unnecessary questions or making unnecessary comments.

In a truly intelligent system, User Model knowledge is acquired indirectly by monitoring user activities in a Task Model. If the system observes the pilot carrying out a particular plan, it is assumed with a fairly high degree of confidence that the pilot understands that process.

If the system determines there is a high probability that a pilot needs complementary or otherwise supporting knowledge, that could signal a need to offer that information. The system must be able to gauge the importance of communicating the information in order to establish whether it should be done and what method should be used for doing so. For example, if human safety is at risk, the operator might need to be informed immediately. In contrast, advice on tasks efficiency would better be presented after the completion of the entire mission.

## World Model

The World Model contains the software's knowledge about the external world: the objects that exist in the world, their properties and the rules that govern them. Those rules can take on a wide variety of forms, such as physical (e.g., the principles governing the effect of aircraft controls on flight parameters), psychological (e.g., rules describing human behaviour in situations of high cognitive workload) and cultural (e.g., rules associated with tactics commonly employed by adversaries).

In the case of a support system for CF-18s, the World Model likely would contain:

- geographical knowledge of terrain and political boundaries or access to such knowledge maintained by a Geographical Information System (GIS);
- principles of flight dynamics and aircraft control and their implications;
- information about the enemy, including targets, equipment and tactics.

There also are needs for mission scenarios and rules of engagement to be stored in a knowledge base and such information would be suitable for the World Model.

## Dialogue Model

The Dialogue Model contains knowledge about the manner in which communication takes place among the pilot and the system (or its agents). Such communication would involve interaction between the pilot and overall system and possibly agents of that system.

Since it is possible that there will be multiple agents in the CF-18 system, it will be essential to specify a common language and protocol for communication among them. In addition, effective user-system and system-system collaboration will require explicit representations of communication provided by the Dialogue Model.

Finally, the Dialogue Model must be designed to permit feedback in agent communication since EMD and PCT rely on the presence of effective feedback.

## Plan Recognition

The ability to recognise user plans is an important element in EMD and enhances the system's "awareness" of what a user is trying to accomplish so that it can decide how best to offer assistance. It is the infrastructure of intelligent, adaptive aiding. One implementation of an EMD system has incorporated techniques from the COLLAGEN approach developed by Lesh, Rich and Sidner (1999).

COLLAGEN uses a "recipe" approach whereby plans that the user may be pursuing are assembled from **plan fragments**. When an interface action is observed by the system, the *fragments* are assembled to form plans that explain why the user performed that action, and there may be many possible plans. As further user actions are observed, the choice of plans that encompass that series of actions diminishes, leading to a more accurate determination of the user's true plan.

The EMD implementation of COLLAGEN mentioned earlier does not provide all the functionality of that technique. For example, COLLAGEN provides for clarification dialogues in which the system prompts the user when there is ambiguity in determining the current plan. That ability could be useful in the CF-18 system, but the system would need to ensure that such prompts did not disrupt the pilot's operation of the aircraft. Such communication should be represented in EMD's Dialogue Model.

## Plan Generation

**Plan generation** is the process by which the system develops strategies for accomplishing its goals to assist the user. It is based on System Model knowledge of a hierarchy of available support goals and plans, Task Model knowledge of the user's current goals and plans and User Model knowledge of the operator's preferences and abilities.

Plan generation in the generic framework would seek to construct the most effective plans for the system to help the controller, e.g., by taking over control of sub-systems under circumstances for which that control had been assigned or monitoring mission status, depending on the selected level of automation.

## Feedback

The concept of **feedback** is important in EMD for establishing mutual understanding and support between the user and the system, enabling one agent to inform another of its goals, plans and knowledge. Feedback can assume multiple forms, both explicit and subtle.

Explicit feedback can occur in the form of dialogues among agents. For example, the system may ask a user whether he or she is familiar with a particular concept. The user's response constitutes feedback to the system, providing knowledge for the User Model and therefore enabling the system to offer more appropriate assistance. Similarly, a user might ask the system to explain its last action, particularly if that action was performed on the system's own initiative. The response from the system is feedback that gives the user a better understanding of how the software operates. The communication of explicit feedback among agents is governed by the Dialogue Model, which must be designed to support exchanges among agents involving the provision of feedback.

A less overt form of feedback arises in the form of system support goals and user goals. For example, if a user's goal is to open a window in the software interface, the system will have a corresponding support goal to display that window. The display of that window constitutes feedback to the user that the goal of opening the window in the virtual environment has been achieved. Representations of user goals also are important forms of feedback since they are the primary means by which the system knows and learns about a user. Detecting user goals is detecting feedback in that those goals implicitly inform the system of a user's plans, abilities and preferences.

The role of feedback in Perceptual Control Theory (PCT) (Hendy, Beevis, Lichacz and Edwards, 2002; Powers, 1990) control loops would bear closer inspection for its contribution to feedback in this context. The concept of feedback could help support an integration of PCT and EMD components in designing and implementing the CF-18 intelligent help system.

## The PACT Approach and Automation Levels

Since it is unrealistic to expect that all users will require the same level of automation from an intelligent system at all times, a need exists for users to be able to specify their requirements of the system. In the CF-18 domain, circumstances of a particular mission and pilot preferences will dictate what automation level is most appropriate, and there is some possibility that those might change within a single mission.

One method of handling automation levels in the air domain was developed for the Cognitive Cockpit (COGPIT) project by DERA in the United Kingdom (Taylor, 2001). Known as Pilot Authorisation and Control of Tasks (PACT), the system is based on the notion of **contractual autonomy**, in which the user and system establish an agreement, or **contract**, on the system's responsibilities. *Contracts* are made using a system of six levels, numbered from 0 (no automation) to 5 (fully automatic). Table 1 shows the levels of autonomy in the PACT approach.

*Table 1: PACT levels of autonomy*

| Levels | Operational Relationship | Computer Autonomy | Pilot Authority |
|---|---|---|---|
| 5 | Automatic | Full | Interrupt |
| 4 | Direct Support | Advised action unless revoked | Revoking action |
| 3 | In Support | Advice, and if authorised, action | Acceptance of advice and authorising action |
| 2 | Advisory | Advice | Acceptance of advice |
| 1 | At Call | Advice only if requested | Full pilot, assisted by computer only when requested. |
| 0 | Under Command | None | Full |

*Contracts* in the context of a CF-18 mission should offer pilots the ability to set the autonomy level, with some scope for change during a mission, as well as provide the flexibility to customise the provision of specific forms of assistance. That customisation should allow a pilot to request help at specified intervals or to ask that help be provided in a specified form.

# Software Agent Paradigm

## Overview of Agent-Oriented Development

An autonomous software agent is a programme with the ability to sense its environment and to act on that environment over time to achieve some purpose and to influence what it will sense in the future (Franklin & Graesser, 1996). Agents can be distinguished further based on their characteristics, for example, **communicative** agents can interact with other agents or people; **adaptive** (or **learning**) agents can alter their behaviour based on past experience; and, **mobile** agents can move themselves to other machines.

The agent-oriented development paradigm offers several advantages that were not addressed by earlier object-oriented approaches, including:

- increased modularity;
- enhanced reusability;
- improved organisational effectiveness;
- increased speed;
- increased reliability;
- better distribution.

Programme modularity is a persistent goal in software development to improve the organisation and reusability of software components. While traditional object-oriented design allows programmes to be sub-divided into modules, the agent paradigm takes that a step further by separating software functions into an array of individually-acting programmes. Those components can be reused and combined with other agents to create new, and potentially very different, pieces of software. Modularity can also serve to improve the organisational effectiveness of software, whereby a suitable division of labour among software components can lead to improved functionality, e.g., by enabling the software to find better solutions or to avoid errors in the process.

Agents also can improve the speed at which software operates since they inherently operate independently. Their concurrent operation allows each agent in the system to act as soon as it perceives a reason to do so, and without waiting for other components to complete their tasks. While some situations require one agent to finish before another can begin, there are also circumstances in which the first agent can provide partial results to the second agent prior to completion of the task, thereby increasing efficiency. Further speed gains can be made through distribution of agents on multiple platforms (see below).

The agent approach can increase reliability through redundancy. When a single programme is running on a network, it may not be able to operate at all times as a result of network instability or system maintenance. In contrast, when multiple instances of an agent are operating in different locations on the network, they can all be working toward a common goal without the same susceptibility to problems on the network. In such situations it is important that the individual agents be able to communicate with one another to co-ordinate their activities. Co-ordination also requires that agents maintain an understanding of what other collaborating agents are doing, as well as strategies for determining the best actions to achieve the common goal.

Distribution is another inherent advantage to agent-based software. The distribution of agents over a network can allow software to make better user of available processing power by dividing a large task into smaller sub-tasks handled on separate machines. That use of agents is especially important for computationally intense tasks, such as those carried out within a knowledge-based system. As with the previous example, distributed agents require the ability to co-ordinate activities through network communication, awareness of other agents' activities and strategies for accomplishing the common goal.

The ideas for software agents have been around since the late 1970s, but the approach did not enter into widespread use until the 1990s. Much of the initial work on agents came out of the (distributed) artificial intelligence (AI) community because autonomous agents naturally lend themselves to AI approaches. More recently in AI, Wooldridge and Jennings (1995a, 1995b) had a significant role in fostering substantial interest in autonomous agents as a software development paradigm. With the current widespread adoption of Internet and intranet technologies, the opportunities for using agents continue to expand.

The success of the agent paradigm has led to its use in a wide range of fields, including AI, knowledge management, human-computer interaction and Internet-based application development. The last category includes information search and retrieval as well as personal software agents responsible for scheduling or making purchases on behalf of a human user.

## Agents in CommonKADS

The CommonKADS (CK) methodology (discussed in the "CommonKADS Methodology" section at the beginning of this report) is entirely consistent with the use of software agents. The Agent Model in the methodology allows for systems with multiple human and software components.

The developers of CommonKADS have provided an example to illustrate the feasibility of designing a distributed multi-agent system using the methodology (Schreiber et al., 2000). The example begins by noting that as a consequence of the European deregulation of the electric utility industry, the business of "generating, distributing and billing customers for kilowatt hours…is being transformed into offering different kinds of new value-added customer services" (pp. 220-221). In Sweden, one of the anticipated service applications is that the electric nodes will act as intelligent agents. CK developers refer to such a system as, "Homebots." In that system, each electricity customer would have a software agent negotiating on his or her behalf with software agents representing the power company. The system would operate continuously, allowing both consumers and suppliers to obtain favourable rates on electricity according to current supply and demand constraints.

While that example involves a more distributed network of agents than would be suitable for use in *LOCATE*, it demonstrates the suitability of CommonKADS for engineering and managing systems with multiple agents.

A Multi-Agent System extension of the CommonKADS methodology (MAS-CommonKADS) has been proposed by Iglesias, Garijo, González, and Velasco (1996). The methodology was developed to add specific agent-related constructs, including those relating to: (a) inter-agent communication; (b) the division of tasks among individual agents; and, (c) the implications for implementation of multi-agent systems.

The Communication Model in CommonKADS is primarily focussed on interaction between the user and individual system agents, with little attention paid to communication among the system agents themselves. To address that issue, MAS-CommonKADS incorporates a Co-ordination Model, which specifies how messages are exchanged, the communication protocols and the abilities that each agent has for interacting with the others. Because of the many commonalities between the Communication and Co-ordination Models, the latter could be treated as an entity within the former.

The division of tasks among agents is an important consideration in the MAS-CommonKADS approach. The physical locations of agents and connections among them can influence the assignment of responsibilities to each component. The division of tasks also will affect the knowledge requirements of each agent.

The multi-agent approach also influences the construction of Design Model specifications. Consideration must be given to network facilities and transfer protocols according to hardware and software constraints. MAS-CommonKADS addresses those issues.

## Agents in Explicit Models Design

Explicit Models Design (EMD), described above, also supports multi-agent system development. EMD recognises the roles of the User and System as agents and allows for the involvement of both multiple human users and system agents with each represented by its own User or System Agent Model.

The EMD Dialogue Model provides a framework for describing communication among multiple human and system software agents. That model allows for various modes of communication, including the following, relevant to the help system:

- the system providing help information and requesting acknowledgement from the user;
- the system prompting the operator for clarification feedback about user goals;
- communication among system agents to co-ordinate activities.

As indicated earlier, the System Model in EMD represents the system as a set of co-operating autonomous agents. Provisions are also made for external agents to play a role supporting the goals of both human users and system agents. That technique has been demonstrated within the context of *LOCATE*, where agents monitor certain user actions that serve as triggers for information-retrieval activity from selected sites on the Internet (Edwards, Scott and Hendy, 2004).

## Multi-tasking and Conflict Detection

Agents provide a natural way of supporting multi-tasking. A system that is conceived as a society of interacting agents would easily lead to assigning particular behaviour to those agents and, in critical situations, assigning an agent its own processor. One possibility for a comprehensive multi-tasking system would be a virtual environment in which each object is a separate agent. Co-ordination of the many low-level agents would need to be handled by higher-order structures (agents). Those "higher-order agents" were described earlier in the section on Explicit Models. Each model, as with the lower-order agents could be assigned a separate processor.

The challenge of parcelling the knowledge seems clear enough at the lower levels, however, if they are to participate in adaptive and intelligent help for a pilot, they would either have to interpret behaviour associated with themselves in terms of that help or they would have to pass information to the model layer whose job it would be to do that interpretation. The knowledge and inference process as well as the sharing and co-ordination of knowledge are key challenges in this kind of design.

Two large projects in which multi-tasking has been explored are Pilot's Associate Programme and the Rotorcraft Associates Programme. Some comments that relate those programmes with the plan recognition work in *LOCATE* are relevant here.

## The Associates Programmes and Plan Goal Graphs

The Associates programme was a US effort that included both the Pilot's Associate Programme begun in the late 1980's and the Rotorcraft Associates Programme that followed in the 1990's. The latter programme extended work on an intelligent associate concept with the aim of building "a reusable, portable, virtual co-pilot in advanced Army rotorcraft." (Andres, 1997, p. 2)

An Associate is viewed as an intelligent aiding system. Of particular interest in that work is intent interpretation which, in the Rotorcraft Programme, gave rise to a "Cockpit Intent Estimator" that served as an intent interpreter. Its function was to determine the meaning of actions in terms of an understanding of "intent, situations in the external world, and knowledge about acceptable behavior in the cockpit." (Andres, 1997, p. 2)

In determining intent, the research used a Plan Goal Graph (PGG) methodology. A PGG is a hierarchical knowledge structure comprised of "a task-analytic decomposition of the purposes of all of the agents that are interacting in a larger macro-system context." (Geddes, 1994, p. 1). It is a directed acyclic graph that is both an abstraction and a compositional class hierarchy.

The work is based on that of Wilensky (1983) and the intent interpretation proceeds by finding a path from the action of an agent up through the PGG knowledge graph to instances of known plans and goals. New plan and goal instances can be inferred as a consequence of the search. Newly created nodes are examined for (several different types of) conflict with other nodes, which represent the actions of the other agents in the macro-system (Geddes, 1997).

In their work on large scale models of intentions, it was observed that such models either could be distributed across computing resources or located in some central resource. In the former case, separate processes would share the results of their intent interpretations by passing Plan

Goal Graph node data. Those data are high-level summaries of agent activities and, as such, save network bandwidth by avoiding the need to send low level activity details.

## Multitasking for the CF-18: Help from the Associates and the *LOCATE* Projects

To return to the requirement for multitasking for goal and plan tracking, one method, the Plan Goal Graph of the Associates programme, has already been given a cursory review. A few summary comments are in order with regard to that methodology, the *LOCATE* approach and the associated programmes of research.

Any work by DRDC Toronto to build a support system for the CF-18 will differ from the Associates programme in that the intent of the former, from the documents reviewed, is to provide aiding to a single pilot in a single aircraft. In contrast, the Associates programme had a broader scope, namely, targeting teams of agents that work co-operatively, such as the commander and gunner of a Battle Tank or members of a submarine attack party who are executing complex attack tactics.

Although multitasking is a concern in both approaches, it is clearly not as demanding for the CF-18 work. Future extensions to the programme could change that of course. Those might include modelling multiple adversarial as well as co-operative agents.

The *LOCATE* programme of research is now a testbed for exploring ideas on plan recognition and generation in the context of intelligent aiding for the users of applications. This is a recent focus and, although the partitioning of knowledge into the different models clearly creates a context for multi-processing, those issues have not been designed into *LOCATE* as yet. In addition, work with *LOCATE* has been concerned with a single user of the system, unlike the team approach of larger macro systems.

It is clear that both the User and System models in *LOCATE* imply multiple interacting agents that could be implemented as separate processes. The data structures and all of the code within *LOCATE*, responsible for tracking user interface actions and providing help to the user, are isolated from the basic functionality of the *LOCATE* tool itself. In principle and in practice, it would be relatively straightforward to partition the former into separate activities of System and User and assign those activities to separate processors, as indicated at the beginning of this section. That kind of multitasking seems all that currently would be required, if that.

Further, the principal extension would seem to involve task allocation *qua* automation in the CF-18 environment, yet tracking the activities of automated systems at anything other than the highest level of what task it is performing has not been identified as a requirement in work thus far. If there is any doubt about what the automated system will be doing at any particular time, then that function may prove useful.

Multitasking also may be an issue if the pilot is pursuing a number of distinctly different goals at once. In all likelihood, there will be occasions in which the pilot will be alternating between several different subgoals of some higher level goal and there would be a requirement for understanding that activity. What would be involved would be maintaining the existence of multiple goal and plan objects, which does not appear to be a problem and can in all likelihood be handled by a single, fast processor. Even if the pilot were pursuing multiple tasks, it would only require that multiple instances of task objects be maintained.

Issues of scheduling and threading of goals, plans and actions will need to be addressed, but the demands for multitasking by the goal and plan tracker are not likely to be excessive and could be accommodated by a revised *LOCATE* tracking system.

In principle, the approach taken in *LOCATE* is consistent with the descriptions offered for Plan Goal Graphs by Andres and Geddes, cited above. One aspect that has not been incorporated into the *LOCATE* system is detection of conflicts among goals. Although conflicts will certainly occur in multi-agent systems, they are much less likely in a tightly organised, interdependent system such as that of a pilot and an aiding system in the CF-18.

Further study of the intent interpretation algorithms used in the Associates programmes would help determine what aspects might be of use to an adapted *LOCATE* system for plan recognition. This may not be possible, however, given the proprietary nature of those algorithms.

## Conflict Detection

Classification of goal relationships will motivate an exploration of how they should be accommodated to build an adaptive aiding system for the CF-18. The following is a modification from Wilensky (1983), and shows one way to classify goal relationships:

***Table 1.*** *Goal Interactions*

| | **NEGATIVE INTERACTIONS** | **POSITIVE INTERACTIONS** |
|---|---|---|
| **Internal** | Conflict: Mutually opposing goals held by a single entity (person or machine) | Overlap: Goals achieved more easily together than apart. |
| **External** | Competition: Mutually opposing goals held by different entities (people or machines) | Concord: Mutually beneficial goal possessed by several entities. |

Competition, co-operation and co-ordination of those different relationships among goals, within and across entities, needs to be accommodated within any tracking system that supports intelligent aiding. Further exploration concerning how they can be incorporated within the CF-18 environment will be the subject of subsequent work.

Comments and questions raised here are meant to encourage the elaboration of ideas for the current application. Achieving that goal will provide real opportunities for mutually beneficial discussion and effective refinement and extension of adaptive system building.

## Design and Implementation for the CF-18

The current project examined two theoretical approaches to construct a comprehensive, integrated framework for the design and implementation of an intelligent, adaptive agent-based system for the support of CF-18 pilots. The resulting framework is composed of elements from the two design approaches including aspects of the agent paradigm as it relates to each:

- **CommonKADS (CK)** – a knowledge management and engineering methodology that guides the systematic analysis and design of intelligent systems;

- **Explicit Models Design (EMD)** – a methodology for building models that identify and compartmentalise the knowledge required by intelligent systems.

Overviews of those approaches were given, and common and complementary elements have been highlighted in the discussions. The integration of the above techniques into a more comprehensive, cross-disciplinary design approach should serve goals of reducing pilot workload while generating a robust, maintainable and reliable help system for the CF-18.

The following is a description of the recommended procedure for designing and implementing a knowledge system within the proposed framework. Steps are designed to be pursued in the sequence presented.

To facilitate the presentation of the procedure, a legend is provided of the two models that comprise the CommonKADS (CK) knowledge and engineering methodology and those used in Explicit Models Design (EMD).

**CommonKADS (CK):**

- Organisation Model;
- Task Model (CK);
- Agent Model;
- Knowledge Model;
- Communication Model;
- Co-ordination Model (MAS-CommonKADS);
- Design Model.

**Explicit Models Design (EMD):**

- Task Model (EMD);
- User Model;
- System Model;
- Dialogue Model;
- World Model.

## Proposed Approach for Managing and Engineering Help

- Construct the Organisation Model to describe the command and control structure within which the project will be developed;

- Construct the Task Model (CK), including task hierarchies for all agents identified above (use IDEF3 to represent the hierarchies);

- Construct the Agent Model identifying all user and system agents and their relationships;

- Generate the Task Model (EMD) by extending the Task Model (CK) to produce task hierarchies for all agents;
- Develop the User Model according to the need to track user preferences and knowledge;
- Specify the content of the System Model to enable representation and use of system preferences and knowledge;
- Design the World Model to contain required information about the environment necessary for the knowledge system to operate effectively;
- Specify the Dialogue Model, Communication Model and Co-ordination Model to govern the format and content of communication among agents (ensure that the ability exists for agents to provide feedback to one another);
- Consider IDEF5 for the design of an ontology to represent the contents of all Explicit Models;
- Develop the Knowledge Model to encapsulate the ontology and an associated knowledge base containing information from all Explicit Models;
- Within the Knowledge Model, represent the Task Model (EMD) using plan recognition and plan generation to form input and output behaviours;
- Accommodate multi-tasking and goal conflict detection and resolution as part of the Knowledge Model;
- Create the Design Model to produce design specifications for the target knowledge-based system.

## Developing a Knowledge Representation Scheme

As indicated earlier in this report, intelligent aiding within the CF-18 domain will require a system that understands what the pilot is doing by maintaining a representation of the mission goals and tracking the pilot's execution of plans to achieve those goals.

In early work on the *LOCATE* workspace layout design tool (W7711-9-7564), an infrastructure was created to track each interface action by a user, infer user goals and identify the plans a user executes for achieving those goals.

Again, as indicated above, to have true intelligence and adaptiveness, a system must "understand": 1) what users are doing; 2) the knowledge and attributes of those users; and, 3) its own features and capabilities that may be helpful to users in a variety of circumstances. To extend that understanding in complex situations like that of a CF-18, it must have the ability to reason about information contained in its various knowledge sources and be able to use the results of that reasoning to provide effective help.

An intelligent aiding system for the CF-18 environment must support adaptiveness during the performance of the task through intelligent aiding for pilots as they execute their mission. The system must "understand" many external events encountered during that mission and accommodate them in building a representation of what is happening. Uncertainty in understanding the goals (motives) of a pilot in such a critical environment exposes the less than optimal capabilities of software systems, which are far less robust and accurate than human inference. Human inference itself, directed at understanding motives, is far from accurate and the results of that inference often differ widely among individuals. Still, it is possible in the context of mission execution to construct useful representations given that much of what the pilot does is "scripted."

A key challenge for an intelligent, adaptive system is to maintain a common plan for itself and the user, as it performs its inference. The approach recommended for helping with the establishment and maintenance of a common plan is the Explicit Models Design representation of task, system and user described earlier. As indicated, instances of those models are in use in the *LOCATE* workspace tool and form the basis for the first steps in bringing adaptive aiding to the CF-18 environment.

While parcelling knowledge into the various EMD models provides a manageable way of understanding the roles and activities of the pilot and the system, and the part they play in performing local tasks and the overall mission, such knowledge will not be organised into the separate models in what follows. The remainder of this report will identify, however, templates for representing the knowledge expressed in the CMS and will use those templates in developing a first approximation for the knowledge contained in the CMS. Subsequent work will organise those representations into the appropriate EMD models.

### Templates for Representation Scheme

As representations began to be developed for the Composite Mission Scenario (CMS), it became clear that they could be summarised in the form of pseudo-code templates that could be refined and extended in representations for other scenarios in future. Key templates were constructed for a variety of elements that were found in the CMS. Key items included in those templates appear in Table 1, below.

***Table 1: Template Items for Pseudo Code***

| | | | |
|---|---|---|---|
| Goal (Intent)<br>(Example Types: Mission; Tasks; Taskings)<br>Pursuers | Event<br>(Activity; Operation; Deployment; Crisis; Petition) | Paraphrase<br>[e.g., Cause; Reason-for] | Qualification<br>Object<br>Action |
| Plan<br>Sub-goal<br>Action | Object<br>Attribute | Time | Frequency |
| State<br>[e.g., Fact; Goal] | Proposition<br>[e.g., Allegation; Assertion; Claim; Threat] | Location | Language<br>(Object Types: Noun;<br>Verb (Number; Tense; Voice); Verb combinations) |
| Relation<br>Causal (Cause-of; Reason-for; Caused-by)<br>Structural (e.g., "section (formation) integrity" | Equivalence | Count<br>[e.g., NUMBER-OF] | Implications<br>X advises Y to do A<br>[A is then assumed to have occurred by what follows.] |

Annex 2 presents the templates used in the pseudo representations for the mission scenario. Concurrent with future work on developing help capabilities for the CF-18 environment will be a further refinement of those templates, how they will be used in reasoning about the events described during a mission and how they will be used to provided help to a pilot.

## Knowledge Representation Scheme for the CMS

Annex 3 presents a complete analysis of Section Five—Composite Mission Scenario of the CF188 APG-65 Radar Human Factors Engineering Study Mission Analysis Report prepared by BAE Systems Canada Inc. (2000). The content of the Annex consists of a review and representation of the activities in that scenario, using the pseudo code representations described above and in Annex 2. As indicated, further work is needed to refine the representations and develop more consistent rules for the expression of tasks, goals, plans, actions, events and the many other items that make up this and other scenarios.

One significant outcome of the analysis to date is a recognition of the need for a structured world model that permits various inter-related facts to be represented, such as those that deal with relative information such as "first," "second" and "last," time references such as, "at this point," summary expressions, such as "the missile engagement," "section (formation) integrity," etc.

Another is the need to permit various kinds of paraphrase, e.g., the ability to convert expressions such as goal (intent) expressions into goal (state) expressions once goals have been satisfied, been suspended or have failed.

A third need is the representation of the many implications found in textual material. A frequent example in this scenario occurs when there is a use of the expression "X advises Y to do A." Often, there is no descriptive follow-on, only the implication from the textual material that follows that Y has performed A.

The next step in the process will be to refine the expressions and identify and resolve areas of inconsistency. Once the knowledge representation rules are finalised, another set of rules needs to be constructed for parcelling that knowledge into its appropriate EMD models and a third set defining how the knowledge will be used in inference. Part of that inference capability will emerge from the development of rules for how "what is happening" can be interpreted in terms of opportunities for adaptive support. Specific help responses by the system need to be identified and all of that work needs to be organised toward building a demonstration that illustrates the system's ability to track what is happening and provide help in intelligent, adaptive ways, when it is useful.

Finally, there are inconsistencies and errors in the knowledge scheme. Refinement will involve the development of a more complete and consistent form of representation for various aspects of the scenario. That effort should eliminate most, if not all of the inconsistencies and apparent errors. Other typographical errors or omissions of items in the scenario will also be corrected. The refinement will be limited by other contractor's progress on a more detailed account of the scenario.

A novel idea emerging from this work and worth further study is the possibility of developing a **recommender** for various adaptive elements based on certain pseudo code expressions and their inter-relations. Beyond efforts to develop a pluggable module for intelligent, adaptive aiding, a *recommender* system would aid in identifying elements that needed to be customised for particular systems.

# A Context for the Study of Intelligent, Adaptive Aiding

## DRDC Toronto's CF-18 Simulation

Work on building a CF-18 flight simulator for the study of intelligent, adaptive aiding is in progress at DRDC Toronto. That work is being done with a view toward building a technology demonstration project (TDP) as an illustration of that work. Proposed work on the TDP provides a good background for understanding a key purpose and current state of work on the CF-18 simulation. The following is taken from a recent TDP proposal:

> Objectives of the Demonstration: The next generation of combat aircraft (either inhabited or uninhabited, fixed or rotary winged) will incorporate advanced display principles and adaptive intelligent interfaces that will assist pilot workload management, and facilitate improved situation assessment. Information management in the next generation cockpit will be a major factor in determining overall capability. The objective of this project is to demonstrate the effects of new interface technologies on mission performance, and to develop the human factor guidelines for their development and future procurement (2015-2020) through extensive use of Simulation and Modelling for Acquisition, Rehearsal and Training (SMART) methods. This project will also develop a facility for specifying and assessing display options for a current procurement activity — the CF-18 Incremental Modernisation Program (IMP). Display and systems options for the CF-18 IMP will be more modest than those projected for the Cognitive Cockpit. However the simulation and modelling environment for this TDP will allow the representation of both current CF-18 systems and those proposed for IMP. Further a CF-18 IMP configuration can be benchmarked against the potentially more capable systems of the 2015-2020 timeframe.
>
> Technology concept on which the Demonstration is based: The Cognitive Cockpit will incorporate dynamic adaptive interfaces for both information display and life support equipment. It will be driven by information about the crew's actions at the interface and by their inferred physiological and psychological states. This demonstration supports TIS areas 7, 8, and 19. The demonstration will consist of a representation of the CF-18 cockpit within DCIEM's [now, DRDC Toronto] ACD environment incorporating adaptive, enhanced SA displays (involving integrated 3D perspective visual displays, helmet mounted cueing/displays (HMCS/HMD), direct voice input, real time planning and replanning, mission aids, 3D audio, and adaptive intelligent personal protection – many of the concepts demonstrated here will be appropriate to CF-18 IMP). Various operational missions will be simulated to demonstrate the differences between "smart" and "dumb" systems. A fly off will be performed between a CF-18 IMP cockpit and an enhanced SA cockpit for two scenarios (a ground attack scenario and an air-to-air scenario).
>
> Value of the Demonstration in providing access to new technology: The UK also has a project called the 'Cognitive Cockpit' with similar aims. Under TTCP we will be able to participate in a collaborative programme of interface development with the UK. Access to the UK information brings approximately $3M in-kind contribution and access to considerable expertise in helmet

mounted display technologies. It is expected that this project will also provide leverage with US programmes such as JSF and the SIRE facility at AL, Dayton OH. The Australians (ASs) are primed to collaborate on CF-18 related projects.

The facility developed under this project will provide a sophisticated tool in support of future combat aircraft acquisition. While CA can monitor similar activities in countries like the UK and USA we will not acquire smart buyer status by being a spectator. Nor is an off-the-shelf US solution necessarily the answer for CA. This demonstrator allows us to develop solutions to the CF-18 IMP and beyond, that are tailored to our CONOPS while interacting with our major defence partners to ensure interoperability.

Related activities in the UK, AS and US provide a window of opportunity to be involved in major technological advances in combat aircraft cockpit design. The timeline is critical. As stated by the lead for the UK Cognitive Cockpit "...We are of course 2 years on, with an almost agreed 3rd year of project funding ahead, and the prospect of bidding for support beyond FY01. The level of funding proposed is approximately £400K, after 2 years at around £500K. So, we are hopefully a good way down the track. However, the level of funding still requires [us] to perform careful scoping and focus to be cost effective. The scope and focus of your proposal looks fully compatible with our program, and at the level of funding proposed, should make a significant additional impact." If we are to maximize our leverage with the UK programme we must start to contribute as early as possible. The other issue related to timing is our contribution to the CF-18 IMP. An immediate start to the TDP will keep us on track for IMP. At the end of year 1 the physical plant will be in place and baseline CF-18 IMP simulation exercises can commence. At the end of year 2, enhanced SA display concepts will be designed and be available for assessment in various operational scenarios. Year 3 will see the fly-offs between various configurations.

Potential impact on the Canadian Industrial Base: Since 1985, BAE System's (formerly Marconi Canada) business plan has included development of a capability to support military operations in the design and evaluation of operator interfaces for aircraft and other systems. It included the development of two Aircraft Crewstation Demonstrators (ACDs) for DND for evaluating the impact of alternative interface technologies on operator performance. The Cognitive Cockpit TDP proposed by DCIEM would have a significant impact on the maintenance—and continued development—of the capabilities currently resident at both DCIEM and BAE. BAE commits to supporting the project in both customer- and company-funded capacities—the former in implementing enhancements as proposed by DCIEM to support the CF18 IMP; and the latter in providing advice and monitoring of the Demonstration. In this respect, BAE is currently involved in other projects that will provide knowledge and expertise that are likely to enhance the facility of the ACD to support the objectives of the Demonstrator.

The proposed Demonstration work is also of particular relevance to ongoing concerns of Artificial Intelligence Management and Development Corporation (AIMDC). Recent research and development at AIMDC includes the implementation of intelligent aiding features through a goal and plan tracking facility. Other related work includes a co-operative effort with DERA Farnborough, to generalize that tracking technology to an emerging goal and plan tracking system of their own. The DERA work is now entering its third year. In the context of those recent initiatives, the proposed work by DCIEM on a Cognitive Cockpit Technology Demonstrator would be both interesting and relevant. AIMDC's goals are to continue research and development efforts in the areas described, so it would clearly be to AIMDC's advantage to provide some substantial support to this TDP. That could take the form of providing advice and consultation on directions of the research from within AIMDC's particular areas of expertise, and monitoring demonstrations of the research with a view to the possible transfer of technology to relevant, industrial areas.

Current state of preparation for the Demonstration, including Project Plan: The current state of preparedness for the demonstration is as follows:

- A theoretical basis for enhanced SA technologies has been developed.
- A representation of a CF-18 cockpit has been built for DCIEM's ACD.
- An intelligent goal-tracking interface has been designed and demonstrated.
- DCIEM has several projects underway involving advanced physiological monitoring.
- DCIEM staff are familiarizing themselves with CF-18 operations.

Although work continues on constructing the CF-18 simulation, much remains to be done to make it a fully functioning system. The current work is focusing on certain aspects of the simulation while others are incomplete, disabled or have yet to be addressed. That state of the simulation means that it will be impossible to implement any test of an intelligent, adaptive support system during the course of this contract work. Moreover, it is not clear whether the simulation will be ready for such an implementation within the next year. As a consequence of those realities, it was determined that alternative contexts should be explored in which intelligent design and implementation could occur.

One alternative involved exploring the possibility of a co-operative arrangement with a commercial company that had developed an off-the-shelf simulation. Two such companies were identified that had (C)F-18 simulations. Another alternative was to look for open source cockpit models that might be adapted to the current requirements. Those and similar alternatives possibly could allow for designing and testing intelligent aiding capabilities while DRDC Toronto worked to bring a full CF-18 simulation on line. Results of the pursuit of those alternatives is discussed in the next section.

## Alternatives Contexts for Adaptive Aiding

After discovering that the CF-18 simulator at DRDC Toronto would not be available during this contract period for building a prototype of an intelligent, adaptive interface, several alternative approaches were explored. The first involved purchasing and examining two commercial, off-the-shelf (COTS) flight simulators, including "F/A-18 Precision Strike Fighter" from Xicat Interactive and the "F/A-18 Simulator" from Jane's Combat Simulations, since discontinued. Those products simulate flight in an F/A-18, the U.S. Navy aircraft from which the CF-18 was developed, and therefore were considered to be suitable for the current project.

Both the Xicat and Jane's software provide a very realistic user experience with three-dimensional representations of both the F/A-18 cockpit and the world outside the aircraft. However, the development of an adaptive interface requires not only that level of realism, but also the ability to customise the controls and displays in the virtual cockpit, and that is where COTS simulators fall short. One product (Xicat) offers some level of customisation using a scripting language, but is limited to developing mission scenarios and lacks support for interface alterations.

In order to achieve the required level of interface customisation for the project using COTS software, access to the programme source code would be necessary. Contact was made with Xicat Interactive to determine whether source code for their simulator could be licensed for use in the CF-18 interface. Xicat referred the inquiry to GraphSim, the company that developed the software for Xicat. Discussions were held with one of the partners of GraphSim, however, it was clear that a suitable licensing agreement could not be arranged in the time available in the current project. Discussions continued with a view to arranging an agreement in the event of future funding for this work.

Another simulator that was considered, but not purchased, was Microsoft's "Flight Simulator 2002." Although it offers greater off-the-shelf customisability and has a cockpit model available for a wide variety of aircraft, the software is designed for modelling commercial flight rather than combat missions. Unlike the other simulators, support is provided for changing the layout of cockpit controls, including the precise positioning of individual items. However, that flexibility does not extend to altering the content of displays to the extent that would be required to demonstrate an adaptive interface. The latest offering from Microsoft, "Flight Simulator 2004," includes a software developer kit that provides some support for the customised display of instrumentation, but does not appear to allow access to the low-level system information that the adaptive interface would require, such as the state of user controls.

As a consequence of 911, commercial flight simulators have begun to eliminate terrain information from their applications. Although understandable, those actions further handicap efforts to use commercial products as realistic simulations.

In addition to examining COTS simulators, an investigation was conducted into the possible use of available three-dimensional cockpit models. There are numerous sources on the Internet for aviation models in a variety of formats, such as VRML and DXF, as well as proprietary formats supported by 3D rendering software, such as Lightwave, Maya and 3D Studio. There is an extensive array of models of aircraft exteriors, but relatively few showing cockpit interiors. While a model of the CF-18 or F/A-18 cockpit could not be found, some models do exist for other fighter aircraft.

Even if a detailed model of the CF-18 cockpit were obtained, the issue remains of reproducing other simulator behaviour. That includes modelling terrain, flight dynamics, aircraft system behaviour and display content, as well as handling control input from users. The complexity of those tasks led to the decision that building those simulator components would not be feasible for the current project.

Perhaps the most promising avenue for developing the adaptive interface prototype is to pursue open-source flight simulators. Two examples are "FlightGear" and the "Combat Simulator Project," which are being developed collaboratively on the Internet. Using that approach, numerous developers can contribute source code to the project that can then be reviewed by others and integrated into the simulator.

FlightGear is designed to model civilian aviation and supports a wide variety of platforms, including Windows, IRIX, Solaris, Linux and Macintosh OS X. The availability of source code means that instrumentation and display content could be customised fully and low-level system functions also could be monitored by the adaptive interface. A key advantage to using FlightGear as the basis for constructing an adaptive interface prototype is that it is a mature project that is the subject of ongoing development. A major disadvantage is its lack of combat support.

FlightGear uses another open-source project called "JSBSim" that models flight dynamics, and which could be useful in a CF-18 simulation.

The Combat Simulator Project is designed to model aviation in a combat setting, which would fit better with the types of mission scenarios that a CF-18 would encounter. However, that project has not received the same level of attention as FlightGear and its development appears to have stalled.

In summary, none of the alternatives explored were appropriate in providing the context for implementing a demonstration of an intelligent user interface for a combat aircraft. The most promising was GarphSim (Xicat) and discussions with the principal in that organisation are continuing. Providing a full-context commercial simulator for the (C)F-18 will be useful while DRDC Toronto completes its work on its own CF-18 simulation.

# Issues and Questions for SME's

One of the tasks of this contract was to meet with Subject Matter Experts (SME's) to discuss issues and raise questions that would help in an assessment of the kind of aiding that would be effective for the CF-18 pilot. Unfortunately, due to DRDC personnel changes on the contract and difficulties encountered in attempting to organise meetings with SME's, this was not possible. In future work, such study sessions will be essential to deciding how best to design the help system.

Although there were no opportunities to meet with one or more SME's, topical areas were identified and issues and questions generated that would serve as guides in future meetings. Those include the following and are derived in large measure from an analysis of the CMS:

## Friend-or-Foe Identification

- How does friend-or-foe identification currently work, and what electronic aids exist (e.g., transponders, radar)?
- How much can we reasonably expect the system to know about other aircraft in the vicinity? (e.g., position, speed, bearing, altitude, aircraft type, friend/foe)
- Is the system "aware" of particular aircraft on the radar, or does it merely treat them as blips?
- Does the system use blip size and shape to assist in identifying other aircraft?
- What role does the AWACS play in identifying aircraft and informing pilots?
- What effect does EMCON have on IFF?
- Possibly relevant terms: IFF, EID, NCTR, AWACS

## Re-group/Re-task

- Section splits up after avoiding SAM launch (pp. 5.8 – 5.9) and then must regroup.
- "Agents" in the IAI system could negotiate the regrouping/rendezvous and suggest it to the leader for approval. The system could take into account current aircraft locations, speeds, bearings, altitudes, as well as the original flight path before they got off course.
- The system could offer to automatically reprogram the EGI to get to the rendezvous location.
- This activity is likely not an example of re-tasking because high-level tactical goals remain the same while only lower-level goals change.
- Misidentification of section members as MIG-29's (p. 5.9): consider IFF issues to avoid mistaken targeting of friendly aircraft.

## Formations

- Many different formations are used over the course of the scenario, including: Offset Card, FLOT Crossing, Line-A-Bearing, Battle, Fighting Wing, Double-Attack, Line-Abreast, Lead-Trail, Finger, Echelon and Radar Trail. Clarify these.

- IAI could determine the current formation from either:

    - radar (if it is feasible for the system to identify the section members), or

    - using information communicated by the other IAI agents regarding the co-ordinates of their respective aircraft.

- How useful would an IAI be that could make suggestions on alternate formations based on inferred high-level goals and on flight data (e.g. speed, altitude, if relevant)?

## Equipment Failure

- There are several references to equipment failures in the scenario, e.g., "dolly bent" and "gadget sick." Get clarity on each and SOPs followed in case of failure.

- If, for example, the radar goes down, perhaps information could be routed from another aircraft in the section, and this could be transparently handled by the network of agents. Would this be useful?

- Taking this a step further…say you have four aircraft flying together, each with its own radio, data link, radar, infrared and various other sensors. That provides a great deal of redundancy, which might enable software agents to perform an assessment of the integrity of the various data sources, and in the process compensate for missing or inaccurate data from malfunctioning equipment.

## Presentation of Data

- What night-vision capabilities exist and how is that information made available to the pilot?

- What alternate methods might there be for presenting existing information (e.g. colour-coding, graphical displays of numerical data)?

- How might data be melded from a variety of sources, such as radar, infrared, visual wavelengths, satellite data, maps (both political and physical)?

## Programming of EGI

- What makes up the "mission data" that is fed into the EGI?

- Does this primarily function as a GPS whereby a series of waypoints are entered?

## Course Detection

- Consider the "racetrack" pattern adopted by the section while they await rendezvous with the Tornadoes (see p. 5.6). Identify others?
- Would it be useful if the goal and plan recogniser was able to identify that a pattern was being flown repeatedly and offer to reprogram the EGI to maintain the detected pattern?
- Does the current auto-pilot already support repeated traversal of a specified (potentially complex) flight route?

## Air-to-Air Refuelling

- Could IAI agents help in co-ordinating the refuelling of the section two-at-a-time?
- Because AAR has some unique activities associated with it (e.g. extension of the refuelling probe, maintaining close proximity to VC-10 tanker), there is the potential for the system to be able to infer quickly and with a high degree of confidence that refuelling is the current high-level goal.

## Future Work

The principal work that emerged from this project focused on some of the basic requirements for building an intelligent, adaptive interface for the Canadian CF-18 that will assist pilots in the execution of their mission. The work includes five key components:

- examining earlier work that constructed an infrastructure to recognise user goals and plans for how such an approach might be adapted to the CF-18 domain;
- exploring how the design approach used in the earlier work might be combined with a knowledge engineering and management methodology to construct a more comprehensive methodology that would guide design and development of intelligent aiding in the CF-18 domain;
- studying a select Composite Mission Scenario (CMS) to understand the requirements for knowledge representation;
- developing a complete pseudo-code representation for that CMS;
- exploring temporary alternative contexts for demonstrating principles of intelligent aiding while DRDC Toronto completes work on its own CF-18 simulation.

Future work will extend each of the above. The comprehensive methodology for analysing, designing and implementing knowledge-based help systems will continue to be refined and will incorporate techniques from earlier work.

The knowledge representation pseudo code will be refined and extended with a view to developing broad capabilities to represent knowledge needed in the problem domain. General rules for knowledge representation will be extended to include knowledge use.

Partially decomposing that knowledge into suitable models, useful in monitoring pilot actions and states, will involve not only the separation of knowledge but also its co-ordination.

Finally, discussions will continue on how commercial off-the-shelf software might provide a context for demonstrating intelligent aiding until DRDC completes its work on its own CF-18 simulation.

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# Annexes

1. Section Five – Composite Mission Scenario
2. Knowledge Representation Templates and Examples
3. Representations of Knowledge in the Composite Mission Scenario

# Annex 1

# Composite Mission Scenario (CMS)

# Annex 1: SECTION FIVE – COMPOSITE MISSION SCENARIO

## 5.1 INTRODUTION

The purpose of the composite mission scenario is to provide APG-65 Radar Project team members with a baseline document that describes the key elements, implied requirements and essential system functions. This document will be utilized in the development of the Operational Sequence Diagrams (**OSDs**) and eventually as a reference during the production of the rapid prototype interface design for the APG-65 Radar distributed simulation. The mission scenario reflects the employment of the CF-18 in the air-to-air/Counter Air Operations role and is intended as a means to ensure that all of the top-level functions associated with the APG-65 Human Factors Engineering (**HFE**) study are identified. The functional decomposition of the top-level functions will be reported separately in the Function Analysis Report.

The reason for using a composite CF-18 multi-task air-to-air role scenario is twofold: first, to focus the analysis on mission sequences that are particularly demanding from a workload perspective or are likely to be critical to requirements definition and the eventual design of the user interface; and second, to avoid wasting effort by analyzing functions that have already been analyzed, are unlikely to be critical to overall system performance, or are unlikely to provide any added value.

Although the scenario was written as a straightforward narrative, it was necessary for the sake of authenticity to use some terms that will not be familiar to the non-fighter pilot user. Where this is the case these terms are hilighted and their meaning is defined in Annex A. Some artificialities may appear in the overall mission but only when necessary to ensure that all relevant issues are included during the actual mission execution.

The following rules govern the preparation of the composite scenario:

a. there should be one, and only one, occurrence of each top-level mission function;

b. mission duration is not determined by artificial factors such as aircraft fuel or ammunition loads; nevertheless, mission execution will highly influenced by these factors;

c. re-locating forces in time and/or space is acceptable; and

d. weapon loads and fuel may be replenished as necessary.

## 5.2 AIM

The specific aim of this composite mission scenario is to portray the planning and execution of a CF-18 air-to-air operation which:

a. focuses on the tactical application of air operations solely – not the overarching strategic objectives;

b. integrates the air power capabilities of several different nations and services;

c. exploits the capabilities and roles of the CF-18 while considering its limitations;

d. incorporates an all weather/night aspect to the overall mission profile/taskings;

e. is based on current realistic CF-18 operational training and aircrew proficiency levels;

f. necessitates positive identification in the air when called for by scenario Rules Of Engagement (**ROE**);

g. uses a single ATO, easily disseminated by a Tactical Air Operations Centre (**TAOC**); and

h. relies on comprehensive, timely, accurate and current intelligence which is air focused.

## 5.3 SITUATION

The political situation is illustrated in Figure 5-1. The time is November 1999. The government of country "X" has unilaterally declared an Xarian Economic and Fishing Zone (**XEFZ**), which effectively moves X's territorial waters out to 300 nm, in order to protect its Sea Lines Of Communication (**SLOC**) and, more particularly, its access to the Deep Fathom Fishing Grounds (**DFFG**). The DFFG provide X a critical food staple; moreover, revenue from the export sales of fish products abroad sustains the Xarian economy.

The new Xarian territorial limit encompasses an adjacent, neighbouring and sympathetic island country "Y". It also encroaches on the 12 nm territorial waters of country "Z". County Z has had long standing internal boundary disputes with extremist factions in its northern provinces. These Extremist factions (**E**) have been motivated by perceived ethnic and religious persecution to commit linked but infrequent incidents of terrorism in the northern provinces.

The time is January 2000. Country X has claimed that country Z has discovered oil reserves in the seabed below the DFFG. X's establishment of the XEFZ in November 1999 and this latest allegation have chilled considerably the decades-long indifferent relations between the country's two governing bodies. Clashes involving the boarding and seizing by both countries of the other's commercial fishing vessels have occurred at an increasingly alarming rate. These incidents have contributed to the enormous upheaval and instability in the region in recent months and have caused near panic amongst neighbouring countries and great concern in the UN.

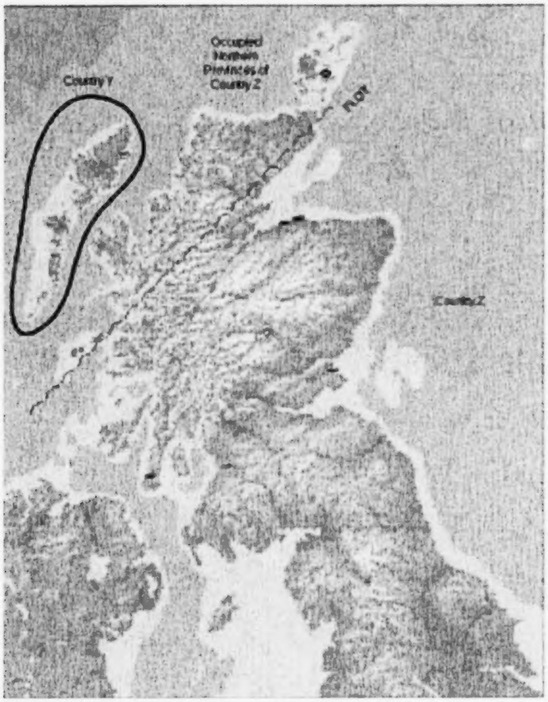

Figure 5-1 Political Situation

The time is February 2000. Countries X and Y have formed a security coalition. At the same time, extremist elements in country Z's northern provinces have ousted the provincial government and laid siege to all major installations in the northern provinces. All Zardian civil authority has collapsed and the provinces are under a state of martial law imposed by the extremist factions. A considerable number of refugees, sympathetic to country Z's governing body, have left the northern provinces for reasons of safety and security.

The time is March 2000. A regional military alliance has been struck between countries X, Y and the extremist groups, E, in the northern provinces of country Z. On the invitation of the extremist groups' leadership, well equipped and armed components of countries X and Y military forces have taken foothold in the northern provinces of country Z. While there is no credible threat of a deliberate military attack on country Z, outside the northern provinces, Z has nevertheless petitioned the UN to intervene with action appropriate to bring the hostile parties (X, Y and E) to a negotiated agreement to leave its sovereign territory and to re-establish the provincial authority and sovereign rule. Such diplomacy and mediation efforts, under the UN Charter, have failed. All effort to negotiate with the provisional extremist government, bolstered by elements of X and Y armed forces, has collapsed.

The time is April 2000. Z has reacted strongly to the crisis and has placed an air and sea embargo on the island country of Y. It has also positioned ground forces along the perimeter with its northern provinces and stopped all flow of people and material into the provinces.

In response to the crisis, country Z has requested Canada to deploy armed forces in support of operations aimed at re-establishing Zardian rule of law on its northern provinces and to assist, as may be required, in the eviction of all X-Y-E armed forces and extremist elements. Canada, through its long standing bilateral security alliance with Z, has agreed to deploy a Squadron of its Reaction Force Air CF-18s. Several other nations have also agreed to support country Z with naval, air and ground forces, logistics supply groups, engineering and hospital support elements, and the like. Armed conflict between the Z Coalition and the X, Y, E forces is inevitable as the deadline imposed by Z for the voluntary withdrawal of the intrusive elements has passed.

The time is May 2000. CF-18s, along with all supporting elements, have deployed to Z. Operational Control of Canada's fighters has been chopped to the Joint Force Commander (**JFC**) appointed by the Zardian Armed Forces Chief of Staff. For the past 2 weeks, CF-18s have been conducting enforcement flights along the perimeter established at the Zardian perimeter (boundary) with its northern provinces.

The time is 0000 Zulu (Z), 21 May 2000. An Air Campaign Plan has been developed and is being implemented. Z-coalition offensive air activity has commenced. An ATO has been issued and Canada's CF-18s have been tasked to provide a multi-role war fighting capability. An ACO is in effect.

## 5.4 MISSION

The ATO assigns a composite mission for a four aircraft flight of CF-18s to support the air campaign plan. The section of four CF-18s is tasked to:

a. conduct a Combined Allied Military Air Operation (**CAMAO**) Route Sweep for a package of 8 UK Tornado GR-1 ground attack aircraft (their task is interdiction of a re-supply choke point on the island of Y);

b. RendezVous (**RV**) with a Royal Air Force (**RAF**) VC-10 Air-to-Air Refuelling (**AAR**) Tanker post Sweep mission;

c. re-commit to new tasking as High Value Airborne Asset (**HVAA**) protection; that is, NATO E-3 Airborne Warning and Control System (**AWACS**) – to include, Mixed Fighter Force Operations (**MFFOs**) with Royal Netherlands Air Force (**RNAF**) F-16 aircraft;

d. RV with a RAF VC-10 AAR, post HVAA mission;

e. re-commit to new tasking to establish (base defence) CAP/Fighter Area of Operational Responsibility (**FAOR**); and

f. recover to a deployment base/aerodrome.

Departure time to commence the mission is 1615Z with recovery at the deployment base at 2100Z. Airspace Control Measures (ACM) are in effect (ACO is valid 1100Z – 2300Z) with Border Crossing Authority (BCA), along the Zardian perimeter with its northern provinces, has been issued to friendly forces.

### 5.4.1 Threat

Collection and analysis of the OPposing FORces (OPFOR) is completed and has established the Air, Ground and Electronic Orders of Battles (AOB/GOB/EOB). The intelligence data applicable for the period of the mission scenario identifies the following threats:

a. **Air-to-Air:** MiG-29 FULCRUM and Su-27 FLANKER employing SLOTBACK - INDIA Band, TWS, Coherent, Look-Down, Shoot-Down, Radar; AA-10 missiles (SAR and IR Variants), AA-11 IR missiles and AA-12 active radarguided missiles.

b. **Surface-to-Air:** a fully Integrated Air Defence (IAD) System and SAM: SA-6, SA-7, SA-8, SA-11, SA-13, SA-14 and SA-16.

### 5.4.2 Planning

On receipt of the ATO at 1000Z, a decision is taken to configure the flight of four CF-18s as follows:

a. two (330 U.S. gallon) external fuel tanks;
b. two AIM-9M;
c. two AIM-7M;
d. two AIM-120;
e. 500 Rounds 20 MM;
f. ALR-67;
g. ALE-39;
h. ALQ-126B; and
i. ALQ-162.

At 1030Z, a flight lead, along with other formation members, are assigned to the CF-18 four-ship (section) mission tasking. The flight lead commences mission planning at 1100Z, coordinating requirements and operations for the Sweep, AAR, HVAA and FAOR taskings. At 1330Z the flight lead contacts the Tornado unit and coordinates the requirements for the Sweep tasking. Commencing at 1400Z, all members of the CF-18 section participate in the detailed mission planning. The mission planning culminates with the CF-18 mission briefing at 1450Z. At 1520Z, the CF-18 aircrew don their aviation life support equipment, gather their mission cards, checklists, classified codes, charts and other mission materials, and step to the squadron operations desk for aircraft assignment, review of aircraft documentation and aircraft sign-out.

At 1540Z the section members proceed out to the restricted area of the aerodrome ramp for aircraft external inspection/walkaround, acceptance and cockpit strap-in.

### 5.4.3 Start and Taxi

At 1550Z the aircraft are started, mission critical data is programmed into the EGI and weapons system checks are completed without incident. The section lead calls for formation status check-in, requests and is cleared to taxi at 1610Z. The CF-18 section taxies to the active runway, staggered with a minimum interval of 200 feet spacing on the taxiway, via the most expeditious routing, and lines up for departure on time, in accordance with the mission briefing.

### 5.4.4 Take-Off and Climb

The CF-18 section lines up on the runway for departure as 2 plus one plus one. Section lead lines up 2,000 feet down the runway, offset to downwind, with #2 on the upwind side of lead and slightly forward of lead's tailpipes. Lateral separation is such that potential directional control problems would not result in a risk of collision on the runway during the takeoff roll. The trailing element, #3 and #4, line up in similar fashion, but to the upwind side of lead's formation and at the button of the runway. At 1615Z, when all aircraft are in position and all pre-take-off checks are complete (#4 calls "4 ready"), lead requests and is authorized take-off. Lead gives the engine run-up signal to his #2 and both pilots run-up their aircraft engines to 80 percent. When both aircraft have completed their final checks, lead initiates take-off roll with a head nod for brake release. Simultaneous with brake release, both pilots smoothly advance the power to full afterburner, with lead aircraft retarding them slightly to allow #2 a small power margin. After lift-off and once safely airborne, the lead element raises gear and flaps, deselects afterburner and accelerates to an en route airspeed of 360 Knots Indicated AirSpeed (KCAS). #3 and #4 take-off in sequence, as single-ships and with 20 seconds spacing on the aircraft in front. The take-off sequence is uneventful. Once safely airborne, the section climbs to 1,000 feet Above Ground Level (AGL), manoeuvres to an OFFSET CARD tactical formation and initiates en route transit to the Tactical Rendezvous Point (TRP).

### 5.4.5 Transit to Tactical Rendezvous Point

During en route transit to the TRP, the CF-18 section, callsign **PULLER**, performs "G" awareness, MODE IV and airborne weapons systems checks, and maintains an OFFSET CARD tactical formation at 1,000 feet AGL. At 1621Z the section arrives at the TRP, extends 2 minutes past the TRP, along the planned Sweep route, and then enters a 2 minute left-hand racetrack pattern, using tactical turns, while awaiting RV with the Tornado GR-1s. During the hold at the TRP all section members complete a **FENCE CHECK**. Lead contacts the Tornadoes, callsign **DIRT**, at the pre-briefed time and the CF-18s adjust their pattern to depart the TRP, OFFSET CARD tactical formation, at 1626:42Z, at a GroundSpeed (G/S) of 420 kts. The CF-18 section leads the Tornado GR-1 8-ship formation by 2 minutes 30 seconds, departing the TRP.

### 5.4.6 Route Sweep

No lateral support has been assigned to the CF-18/GR-1 mission. **AUTONOMOUS CONTROL** procedures are in effect. Accordingly, a reference Bull's Eye (**BE**) has been selected for adversary air advisory and other mission critical calls between the two formations. A graphic depiction of the Sweep mission routing an mission scenario is illustrated at Figure 5-2.

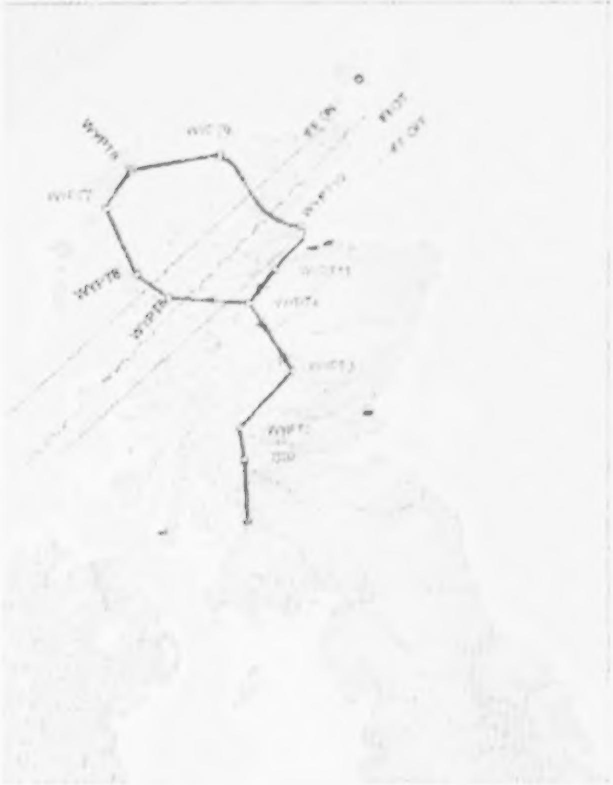

**Figure 5-2 SWEEP/Combined Allied Military Air Operation Tasking**

The CF-18s maintain the pre-briefed section AI radar channelization, search and sort plan discipline, and OFFSET CARD tactical formation integrity, at 420 kts G/S and 1,000 feet AGL, 2 to 3 minutes ahead of the GR-1 package (to ensure that the section is not outflanked and yet able to engage adversary aircraft early, should any be encountered). At route Waypoint (**Wypt**) 2, the CF-18 section joins the ACO Low Level Transit Route (**LLTR**).

Midway between Wypt 2 and 3, along the LLTR, the section encounters an opposing formation of aircraft, appearing to adhere to the ACO. The two sections initially **SPIKE** each other's radars and illuminate each other's RWRs, but 4 x F-16s are subsequently Electronically

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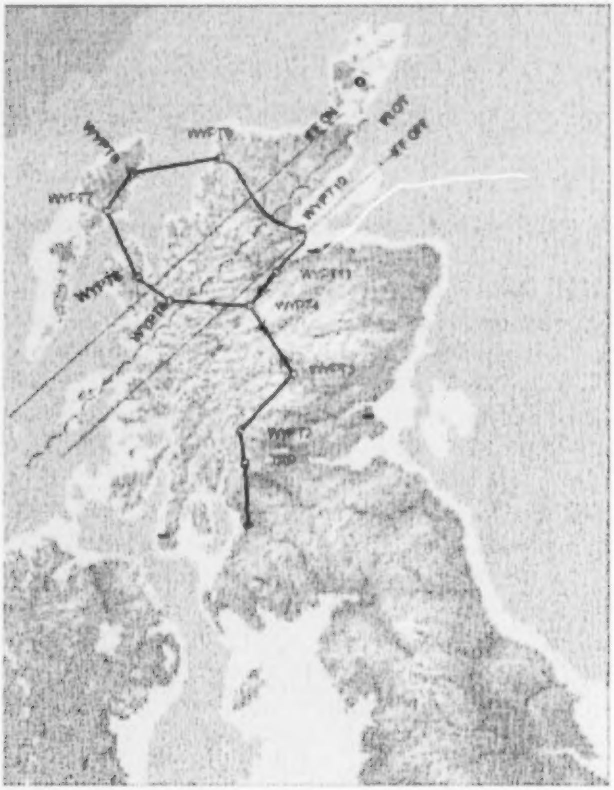

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IDentified (**EID**), by the CF-18s, utilizing APG-65 NCTR processing. The CF-18 section sorts the friendly formation and manoeuvres to enable #2 to positively Visually IDentify (VID) the F-16s pre-merge. This information is communicated to the GR-1 package via common frequency. CF-18 section OFFSET CARD tactical formation and LLTR routing is quickly regained, post merge.

At Wypt 3, the CF-18 section pushes up to 480 kts G/S. No radar, RWR or adversary air visual sightings are encountered during the LLTR transit between Wypts 3 and 4. All is **CLARA**.

Just past Wypt 4, at the IFF OFF LINE, EMission CONtrol (**EMCON**) procedures are implemented by the CF-18 section. Simultaneously, as it is unlikely that adversary AI threats would be encountered in the vicinity of the Forward Edge of the Battle Area (**FEBA**)/Forward Line of Own Troops (**FLOT**), the section collapses to a **FLOT CROSSING** tactical formation and descends to make better use of terrain masking. Section RWRs are illuminated several times by adversary ground-based systems during and post FLOT crossing, but a combination of aircraft manoeuvre, visual lookout, use of terrain masking and employment of active Radio Frequency (**RF**) jammers, enables the section to transit successfully to Wypt 5. No AI threat activity or SAM launches are visually observed.

As the trailing CF-18 element passes Wypt 5, while exiting a coastal inlet and entering an area of small islands, #4 observes from his right 5 o'clock position multiple ground flashes and the unmistakable smoke trail of surface-to-air missile launches. The aircraft are not spiked. On discreet frequency, #4 calls for a missile break/maximum performance turn into the missiles' plane of turn. #3 and #4 deploy chaff and flares from the ALE-39 CMDS, via the panic button sill switch, retard throttles, manoeuvre through 60° of turn into the missiles and rapidly descend to the DECK. One SAM is defeated by a flare decoy while the other acquires surface glint and impacts the sea. #3 and #4 execute a hard 90° turn left to skirt to the seaward of a small island, outside the apparent SAM engagement zone, and track parallel to the pre-planned route. During the missile engagement Lead and #2 push up to full military power and extend along the pre-planned route. Lead informs the Tornado package of the SAM engagement and the GR-1s deviate from track to avoid the missile site.

The CF-18 section (formation) integrity has been compromised by the missile engagement. The trailing element no longer has VISUAL, is now offset to the right 4 o'clock of the lead element by 4 nm and is terrain masked amidst several small islands. Line Of Sight (**LOS**) R/T between CF-18 elements is inhibited. The nearest practical RV is 3 to 4 minutes further along track, at the approximate point where the two elements had pre-planned to deviate from the GR-1 ingress into the IP and TarGeT (**TGT**) area. The two CF-18 elements Sweep the route, independently, in a rough **LINE-A-BEARING** formation, to the RV.

Shortly after the lead element passes Wypt 6, Lead and #2's ALR-67 RWR threat displays indicate acquisition by a surveillance/engagement radar associated with **SA-8** and applicable audio alert tones are heard in the pilot headsets. Lead and #2 immediately deviate from course, collapse combat spread (#2 inside the turn) and manoeuvre to descend between two ridge lines. #2 remains spiked and turns slightly into the threat, to reduce radar cross section, while diverging from lead's flight path. #2's RWR threat display goes critical. He immediately executes a hard turn (4 'G') into the spike and deploys multiple bundles of chaff utilizing the chaff/flare switch on the right throttle. ALQ-126B pulse and ALQ-162 Continuous Wave (**CW**) jammers are in repeat mode. #2 observes two missiles slightly high along his RWR's threat origin azimuth. He immediately turns hard to put the missiles on the beam, simultaneously deploying multiple bundles of chaff. One missile barrels into the terrain on the opposite ridge line and the second appears to have acquired chaff. Lead and #2 quickly regain formation integrity and egress the SAM engagement zone in the general direction of the pre-planned route.

Lead transmits the second SAM engagement in the blind to the Tornado package while offsetting his formation away from the IP, as per the mission pre-brief. Approximately 30 seconds later, just as the lead element rounds an extension of land, Lead is spiked by an AI radar in his right 4 o'clock position. A hard 90° right turn into the threat is executed by Lead and #2. Both aircraft command their APG-65 radars into Auto-ACQuisition (**AACQ**) mode. Miraculously, two sorted radar lock-ons are achieved and the lead CF-18 element manoeuvres for two independent weapons solutions. #2 calls "**HOSTILE**, hostile, MiG 29", fires a **SPARROW** missile and turns hard away from the MiG to maximum radar gimbal limits (**F-POLE**), to the left and north of Lead. It is the trailing element of CF-18 aircraft that has been mis-identified and targeted. #3, having visually identified the lead element on the beam as it rounded the isthmus, calls "**FRIENDLY**, friendly" and commands a radar break-lock. #2 breaks the lock-on and the launched SPARROW goes ballistic and lands in the sea. Lead aircraft calls for an element-element cross turn, to rejoin, and the section extends in **BATTLE** tactical formation to the north, to re-intercept its intended ground track, utilizing the CF-18 digital MMD and EGI as navigation reference.

For the next two minutes Lead and #3 switch to 90° radar azimuth scan centred to look directly into the target area, to the left forward quarter of the CF-18s. From this threat sector, multiple fast and low targets are radar observed departing the airfield in the target area. The CF-18s **JINK** 30° to the right in order to draw the adversary air away from the planned GR- 1 ingress, IP to TGT. An adversary 4-aircraft formation is observed on a hot vector to the CF-18s. Numerous RWR display and audio indications indicate the CF-18s are being sampled/targeted by the adversary aircraft. Additionally, there is much R/T on common tactical frequency, indicating that the GR-1s have also encountered threat activity on the ingress to their target(s).

The CF-18s **FLOAT**, to near radar gimbal limits, such that the lead element only maintains radar contact on the hostile entities, while drawing them away from the ingressing Tornadoes. The GR-1 flight lead calls by the IP, at which time the bandits are 15 nm from the CF-18s, but on an hot intercept course. The CF-18 section executes an element-element near-90° turn into the threat. At 25 seconds Time-To-Go (**TTG**), when Lead's steering dot is in the Normalized In-Range Display (**NIRD**) circle, lead launches an AIM-7M. Almost simultaneously, #2 acquires the lead bandit pair wingman and also launches a SPARROW. Both CF-18s F-Pole to the North and East. The CF-18 lead element RWRs record Pulse Doppler Illumination (**PDI**), indicating hostile A-A missile launch. At approximately 10 nm from the bandits, #3 and #4 are able to acquire, sort, target and launch SPARROWS on the trailing bandits. #3 and #4 F-Pole to the North and West. All launched SPARROWS time out and "**SPLASH** four bandits" is transmitted in the blind to the GR-1s. The CF-18 section egresses to the north and east of the target area, en route to Wypt 9. OFFSET CARD tactical formation is regained. The GR-1s call off target and declare one **LOSER**.

PULLER arrives at Wypt 9 one minute late but still two minutes ahead of the DIRT. The remainder of the Sweep along the planned egress route is uneventful. The CF-18 section flies an OFFSET CARD tactical formation (adjusted as required for terrain), maintains communications discipline and adheres to the pre-briefed threat lookout, search, sort and targeting contract. At the **IFF ON LINE** the CF-18 section turns the IFF on. Midway to Wypt 10, just prior to FLOT crossing, the formation is collapsed. RWRs illuminate briefly in the vicinity of the FLOT but no missile launches are detected on RWR or are visually observed. The section does not deviate from its pre-planned egress route. At Wypt 11, the section slows to 420 Kts G/S. At Wypt 4, the section further reduces speed to 360 kts G/S, commences a climb to the Medium Transit Level (**MTL**), 21,000 feet, and adjusts altimeters to 29.92 (inches of mercury). During the climb, the section encounters inclement weather/Instrument Meteorological Conditions (**IMC**) and collapses to two close-formation elements, with the trailing pair maintaining 2 nm radar-trail on the lead element. At Wypt 3, the section joins the Transit Corridor (TC) and contacts the pre-briefed ground control agency, call-sign HARDTIRE. Lead passes a MISsion REPort (**MISREP**), and receives and acknowledges clearance to proceed directly to the assigned AAR area, SULLY, at Flight Level (FL) 260. At this point, the Sweep mission is deemed successfully concluded. The time is 1715Z.

### 5.4.7 Air-to-Air Refuelling (DAY, VMC)

During the climb and short transit to AAR area SULLY (graphically depicted at Figure 5-3) the CF-18 section enters Visual Meteorological Conditions (**VMC**). A weapons safety check is performed and pre-briefed A-A TACANs are set. Lead checks-in briefly with the RAF VC-10 tanker, callsign **HOSER**, on Tactical Air Designator (**TAD**) 23 and is authorized silent re-join and tanking procedures. Air-to-Air TACAN is showing 60 nm to the tanker, with high closure, suggesting a nose-to-nose pass. Lead obtains a radar contact at 46 nm and initiates a high angle off intercept course, while the other formation members collapse into **FIGHTING WING** tactical formation. At 12 nm, with visual contact on the tanker, the CF-18 Lead requests the tanker to reverse its orbit to the south. Once inside 1 nm, with 80 Kts of closure (Vc), the CF-18 section initiates a climb to 1,000 feet below the tanker (FL270), selects EMCON, slows to 290 KCAS and re-joins outboard of the VC-10's right wing, in the AAR **OBSERVATION POSITION**. At this point #3 and #4 move outboard of the VC-10's left wing. Lead and #3 drop astern the trailing hoses, extend refuelling probes and, when cleared contact by the AAR lights, initiate contact with the refuelling drogue (basket). Once refuelled, Lead and #3 disconnect, move outboard of the right and left wings, respectively, and retract refuelling probes. At this point, the AAR procedure is repeated by the wingmen. Once the wingmen have moved outboard of the tanker's wings and retracted refuelling probes, #3 and #4 manoeuvre to rejoin Lead's element on the right wing. At this point the CF-18 section departs the tanker with Lead and #3 totalling the lowest fuel on board, at 13,000 lb. The time is 1750Z.

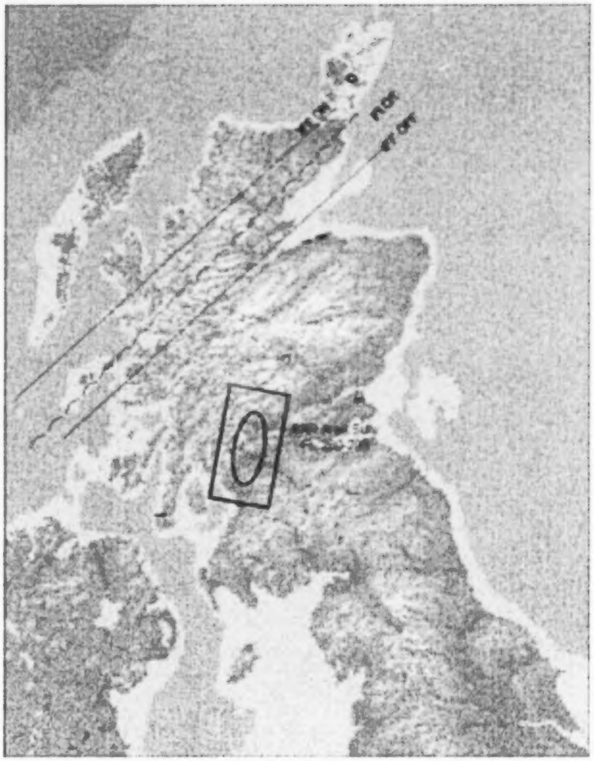


Figure 5-3 Air-to-Air Refuelling Tasking

### 5.4.8 High Value Airborne Asset Protection

A graphic depiction of the HVAA protection mission is illustrated in Figure 5-4. Once clear of the VC-10 tanker, in area SULLY but while en route to its assigned HVAA orbit(s), the CF-18s descend to FL260, accelerate to .85 Indicated Mach Number (**IMN**) and manoeuvre to a BATTLE tactical formation. During the transit, the section re-programs mission data into the EGI, changes AI radar channelization, adjusts radar search patterns and DEWS settings, and conducts FENCE CHECKS, as per the HVAA mission pre-brief. Lead establishes radar contact on the HVAA, a NATO E-3 AWACS aircraft, callsign **MAGIC**, and initiates radio contact, on TAD 17. MAGIC requests the CF-18 section, callsign PULLER, to authenticate and change IFF codes.

**Figure 5-4 High Value Airborne Asset Protection Tasking**

PULLER is then handed off to its tactical INtercept Director (**IND**), on board the AWACS, callsign **SMURF**, on TAD 14. On check-in, Lead gives **ON-STATE** times and weapons loads. SMURF directs PULLER to change callsign to **RED** and **BLUE** and climb to **ANGELS** 31 and 33, respectively, and proceed to CAP datums. Lead authorizes #3 and #4 to leave the section at this point. The section now becomes two distinct (2-ship) elements; specifically, RED and BLUE. LINK 16 is showing the two RNAF F-16s, callsign GOLD, proceeding to their assigned backstop/goalkeeper CAP datum, at ANGELS 35. SMURF advises that LINK 16 has been intermittent and that in the event it goes down, the pre-briefed BE will be used for bogey **BROADCAST CONTROL** calls until the fighters elect to commit out of their CAPS, at which time **LOOSE CONTROL** will be provided. RED is requested, by SMURF, to establish CAP datum hot-leg timings (into the threat sector) for RED and BLUE and to ensure that GOLD flies opposing CAP timing. Area weather is showing an undercast cloud layer (variable from ANGELS 15 to 19) with **CONTRAILS** expected at ANGELS 42 and high cirrus clouds above. The time is 1800Z.

RED confirms the hot and cold legs timings, A-A TACAN channelization, and the radar search, sort, targeting and commit criteria out of the CAP datums, for all three elements, as per the HVAA mission pre-brief. Essentially, the six fighters are functioning as an MFFO, although the CAPs are geographically distinct. LINK 16 shows MAGIC established in a 20 nm figure-eight pattern, in a sanctuary between ANGELS 28 - 30, at its assigned datum, some 70 nm to the south-east of RED and BLUE CAPs.

RED initiates CAP datum hot-leg timings for RED and BLUE at 1807Z. At this point, GOLD turns cold. In the absence of target activity, SMURF transmits CLARA.

At 1810Z, just as the forward CAPS are turning cold, LINK 16 shows multiple targets climbing and accelerating, on a hot vector, some 170 nm from the E-3 orbit point. For the next several minutes, CAP integrity and radar search discipline is maintained by the fighters as the trajectory of the unknowns is monitored on LINK 16. At 1812Z, SMURF advises **DOLLY BENT** and broadcasts bogey updates, from the BE. At 1814Z SMURF broadcasts two distinct target groups; one is trailing by 10 nm but both appear to be maintaining hot vectors to the E-3. At 1815Z, just as RED and BLUE turn hot, the bogeys pass east of the BE datum point. As per the mission brief, MAGIC **RETROGRADES**. BLUE accelerates in afterburner and commits on the bogeys while RED and GOLD maintain CAP discipline. SMURF declares two elements of **BANDITS**, with the lead element at ANGELS 41, Mach 1.2, laterally split 2 nm. MAGIC descends and accelerates, on its RETROGRADE vector. SMURF calls going **ORANGES SOUR** at ANGELS 19.

BLUE lead obtains radar contact on the lead bandit element at 35 nm and transmits Bearing, Range, Altitude and Target Aspect (**BRAA** report). BLUE lead continues to radar sort the formation while his wingman establishes initial radar contact on the trailing pair, at ANGELS 32. At 25 nm to the lead bandits, BLUE 2 advises his flight lead that the trailing pair have **POST-HOLED**. BLUE lead directs his wingman to drop acquisition on the trailing pair and to sort and target side-side on the lead bandits. The CF-18 RWRs are active but do not indicate PDI. At 15 nm the lead bandits initiate a **DRAG/PUMP** and rapid descent. BLUE lead and BLUE 2 are sorted and immediately launch 2 x AIM-120 missiles, transmitting "FOX-3, FOX- 3". SMURF gives BLUE a snap vector to the trailing bandit pair, now at 15 nm and ANGELS 17, Mach .95. BLUE 2 establishes initial radar contact, gives a quick BRAA report to flight lead and EIDs the bandits as Mig-29. BLUE lead and BLUE 2 sort the bandits lead-trail, fire AIM- 7Ms and F-Pole away from one another. Blue 2's RWR indicates a bandit missile launch and he deploys chaff and flares using the CMDS sill switch. SMURF calls "North is **GREEN**". At TTG zero, both BLUE lead and #2 manoeuvre to egress to the north, climbing to ANGELS 33. SMURF confirms four bandits splashed and gives BLUE 2 a snap vector to his lead. BLUE lead reverses course for the CAP datum with BLUE 2 radar acquiring and rejoining in **DOUBLE ATTACK** tactical formation during the transit back. The time is 1821Z.

MAGIC continues to monitor the air situation, while manoeuvring back to its original orbit datum, in its assigned altitude block. SMURF passes CLARA advisories every few minutes to the fighters, as they execute their counter-rotating CAPs. At 1834 BLUE 2 calls gadget **SICK**.

At 1838Z SMURF advises radar contact on a group of bandits, 40 nm west-northwest of the BE, again on a hot vector to the E-3. RED, about to turn hot, vectors south-east, directs GOLD to leave his CAP datum to join RED in battle tactical formation and directs BLUE to assume goalkeeper CAP datum. RED and BLUE acknowledge and comply. MAGIC retrogrades.

At 1840Z, RED calls **TIED**. RED and GOLD turn into the threat sector and commit on SMURF's bandit calls, now indicating BE 230°/20 nm, ANGELS unknown, flight size four. RED and GOLD quickly adjust radar azimuth and elevation scans to bracket the possible bandit flight path(s) and accelerate to supersonic speed. RED lead samples a radar contact at 40 nm and shows 10° Target Aspect (TA), ANGELS 28, Mach 1.1. SMURF confirms the contact but advises a flight size of four, in a rough line-abreast formation. At 30 nm RED advises two radar contacts, one at ANGELS 35 climbing and the other at ANGELS 24 level. RED directs GOLD to target the contact at ANGELS 35. At 25 nm GOLD lead notices a momentary contrail, beaming to the east. At 22 nm GOLD lead and GOLD 2 realize that they sorted two high, supersonic targets, both dragging in opposite directions and away from the bandit(s) targeted by RED. GOLD lead targets the western bandit and clears GOLD 2 off to target and splash the target beaming to the east. RED descends to engage the bandit(s) at ANGELS 24. The R/T intensifies as RED and GOLD attempt to build and relay Situational Awareness (**SA**), transmit engagement tactics and bandit reaction. SMURF confirms the geometry and indicates that RED and GOLD have successfully targeted the bandit formation in two separate, two-versus-two, air-to-air engagements. The CF-18 RWRs indicate that the friendly fighters are also being sampled and sorted by the bandits.

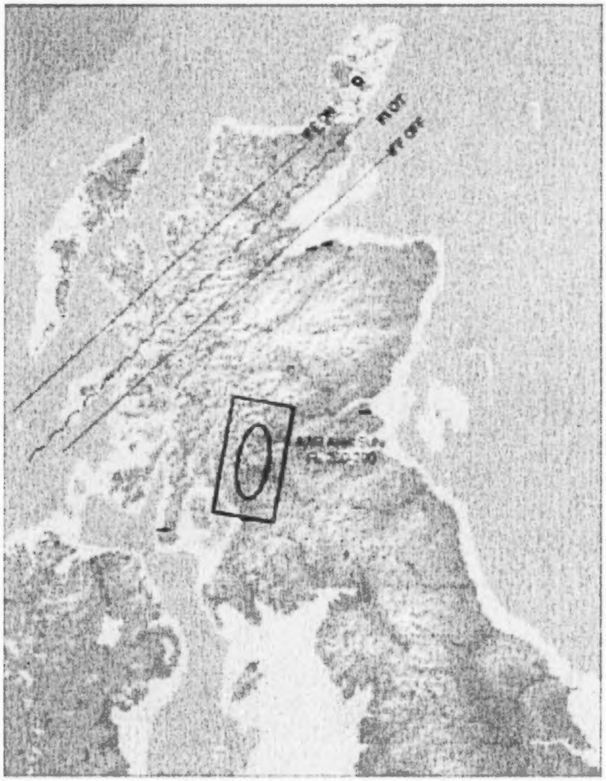
At 18 nm RED lead sorts two bandits, in **RAID** mode, at ANGELS 24 and 21. At 12 nm RED 2 confirms a lead-trail formation, with the wingman offset to the west. RED lead calls sorted, fires an AIM-120 missile at the bandit leader and pumps. RED 2 tries to command a Single Target Track (STT) but is unable. He calls **CLEAN** and presses to the merge. RED 2 observes lead's missile score a kill on the bandit leader and directs RED lead to **PITCHBACK** into the fight. RED 2 makes a high angle-off unobserved entry to the merge, locks on in VACQ mode and manoeuvres out of plane, but is acquired by the surviving bandit and is jammed before he can launch an off boresight AIM-9M. The surviving bandit and RED 2 enter into a neutral **VERTICAL ROLLING SCISSORS** fight. RED 2 calls engaged, neutral. RED lead regains a visual and a **TALLY** and uses his HMS/HMCS to achieve a radar lock-on. He calls engaged, directs RED 2 to **COME OFF RIGHT** and scores a clean AIM-9M kill on the trailing bandit. RED lead directs RED 2 to egress south and they quickly regain visual and **MUTUAL SUPPORT**.

Approximately one minute later the F-16s splash their assigned targets. At this point they are 12 nm apart. GOLD lead directs a **ROUND-UP** at CAP datum but Gold 2 declares battle damage. SMURF immediately provides GOLD lead radar vectors for a re-join with his wingman and hands them off to a new intercept director on TAD 11 for the emergency diversion.

RED elects to join BLUE at the goalkeeper CAP datum and enters that CAP in a counter-rotating set-up at 1851Z. At 1855Z BLUE lead declares 10 minutes **PLAY TIME**. SMURF acknowledges and clears the four CF-18s to rejoin at ANGELS 26 and depart the CAP datum for AAR area SULLY, under callsign PULLER. The CF-18s rejoin in element, 2 nm radar trail (sunset is 1910Z), declare ammo and fuel states, renumber and commence en route transit to SULLY.

### 5.4.9 Air-to-Air Refuelling (Night, IMC)

During the transit to AAR area SULLY (depicted in the illustration at Figure 5-5), the CF-18 section enters intermittent **IMC**. A weapons safety check is performed, and pre-briefed A-A TACANs are set. Lead checks-in briefly with the same RAF VC-10 tanker, callsign HOSER, on TAD 23 and is once again authorized silent re-join and tanking procedures. Air-to-Air TACAN is showing 85 nm to the tanker, with low closure, suggesting a stern pass. Lead requests HOSER to turn to the north-east and obtains a radar contact while the tanker is in the navigation turn. Once the tanker TA reaches 20°, PULLER requests the tanker to roll-out of its turn, to facilitate the radar rejoin. HOSER calls oranges **SWEET** but advises the weather has deteriorated in SULLY and that AAR will have to be done in and amongst cloud layers, in low visibility and night conditions.



## Figure 5-5 Air-to-Air Refuelling Tasking

At 15 nm range PULLER requests the tanker to reverse course to the south-west. The CF-18s collapse from radar trial to a loose FINGER formation, adjusting position and formation lights, and formation separation to accommodate the approaching darkness and inclement weather conditions. During the tanker turn and roll-out on a SW heading, PULLER lead monitors TA, range and Vc, and adjusts angle of bank, power and climb attitude to arrive 6,000 feet astern the tanker with 80 Kts of overtake. By maintaining a radar lock-on, and by monitoring and controlling the position of the Target Designator (**TD**) box in the HUD, as he slows to 290 KCAS and closes on the tanker, lead is able to visually acquire the VC-10. Lead positions the section outboard of the VC-10's right wing and, once settled, clears #3 and #4 outboard of the tanker's left wing. The 2 elements automatically manoeuvre to **ECHELON** formation outboard of the tanker's wings and complete the remainder of the pre-RV cockpit checks.

Once the elements are firmly established outboard, the tanker drops the refuelling hoses. Lead and #3 drop astern the trailing hoses, extend refuelling probes and, when cleared contact by the AAR lights, initiate contact with the refuelling drogue (basket). At this point, darkness has arrived at FL280 and the cloud cover has thickened to near total IMC. Once refuelled, Lead and #3 disconnect, move outboard of their wingmen, positioned on the right and left wings, respectively, and retract refuelling probes. At this point, the wingmen move astern the hoses for contact.

While #2 and #4 are refuelling, the tanker enters a navigation turn to the NE, to remain within AAR area SULLY. The air has become quite turbulent and both wingmen inadvertently disconnect during the turn. #4 is able to re-connect after tanker roll-out but #2 is unable to make satisfactory probe contact with the drogue due to severe oscillations of the refuelling hose and aircraft buffet. After tanker roll-out, on his fourth attempt to re-connect, #2's closure rate results in displacement of the drogue and a violent tip-off. The drogue basket contacts the aircraft's right-side nose area. Almost immediately, #2's master caution light illuminates, along with an "engine right engine right" voice alert and caution display. The resultant warning and caution lights are accompanied by a loss of thrust and #2 drops below and astern the tanker.

#2 makes judicious use of afterburner to safely clear the tanker. After making a controlled descent to level flight at FL260, he notifies flight lead of the emergency but advises he has full control of the aircraft and is able to recover independently. PULLER lead provides #2 **PIGEONS** to the nearest suitable diversion base and clears him for the single-ship recovery. HOSER advises PULLER #2 to contact MAGIC on TAD 19. #2 contacts MAGIC and is cleared to contact **NEATISHEAD** approach control for an emergency landing. The subsequent descent, approach and landing is executed safely and in accordance with emergency procedures for a right engine out and loss of hydraulic 2A pressure (typical of angle of attack vane ingestion into right engine).

#4 successfully completes tanking, moves outboard of #3 on the tanker's left wing and retracts his refuelling probe. #3 and #4 manoeuvre to rejoin Lead on the right wing. At this point the CF-18 3-ship is cleared to depart the tanker. Lead totals the lowest fuel on board, at 13,400 lb. The time is 1950Z.

### 5.4.10 Fighter Area of Operational Responsibility

Once clear of the VC-10 tanker, while en route to its FAOR (graphically depicted in the illustration at Figure 5-6), PULLER descends to FL220, accelerates to .85 IMN, manoeuvres to a radar trail formation (one plus two) and joins the Minimum Risk Routing (**MRR**). During the transit, flight lead compensates for the formation status change. He briefs new AI radar channelization and A-A TACANs, and assigns a search, sort, target and commit plan, based on the new 3-ship formation configuration. Flight members confirm DEWS settings, re-program essential mission data into the EGI and perform FENCE CHECKS, as per the FAOR mission pre-brief. Lead re-names the formation as **STAG**, as per the ATO, but does not re-number, indicating he will fly as with a phantom #2. At 1955Z Lead initiates radio contact with the FAOR mission ground-based radar, callsign **BULMER**, on TAD 12. BULMER requests STAG to authenticate and change IFF codes, and issues FAOR altimeter setting.

**Figure 5-6 Fighter Area of Operational Responsibility Tasking**

BULMER confirms radar contact on STAG and authorizes descent to assigned mission sanctuary altitudes and direct routing to FAOR datum. While en route, STAG transits an adjacent FAOR and is targeted by 4 x F-3, callsign **DART**. The fighters mutually interrogate each other's IFF as friendly. At 2000Z STAG calls **ON-STATE**, with seventy minutes playtime, and indicates that any commit will be done as a 3-ship. BULMER acknowledges with CLARA.

STAG establishes a 20 nm counter-rotating CAP at FAOR datum, at 370 KCAS, at ANGELS 11 for lead and ANGELS 12 for the trailing pair. The hot and cold leg timings are coordinated to ensure continuous fighter radar coverage into the threat sector to the north. BULMER advises LINK 16 is available but that MAGIC has confirmed intermittent LINK 16 operation. BULMER designates a common BE for the adjacent FAORs and indicates able to provide (in the event of DOLLY going bent) broadcast control, only, due to poor radar coverage over the area terrain. BULMER briefs area weather as undercast, five to eight tenths cloud cover from 3,000 to 8,000 feet MSL, with FAOR mean terrain height (variable) at 1,400 feet.

At 2017Z, LINK 16 shows four friendly aircraft transiting diagonally towards STAG's FAOR, in a lead-trail formation along an ACO LLTR, at a G/S of 450 Kts. At a range of 30 nm from STAG's FAOR datum, the 4-ship suddenly deviates from the LLTR and increases G/S. LINK 16 is still showing friendly. BULMER is advised but is unable to confirm status or radar contact. At 25 nm to the targets, LINK 16 shows target status changed as unknown. STAG lead immediately directs #3 and #4, at that time on opposite side of the race track pattern and hot, to rejoin in 2 nm trail. STAG lead turns into the threat and accelerates to 420 KCAS, as he commits out of the CAP pattern. Lead directs a lead-trail sort contract with his wingmen and advises an initial intercept geometry to target the trailing pair.

At 20 nm, STAG establishes radar contact on the bogeys, on-the-deck, at .95 IMN, clearly off the LLTR. LINK 16 is still showing target status unknown. Lead manoeuvres the 3-ship to establish a slightly hot, 150° Heading Crossing Angle (**HCA**) right-to-left intercept course and descends to 2,000 feet AGL (still in cloud). At 15 nm from the lead bogey pair, STAG Lead interrogates the targets as hostile and immediately accelerates to 500 KCAS. He sorts the targets in TWS and notes that the lead bandit closest to him is designated the Launch and Steer (**L&S**) target. STAG Lead extends to the west in afterburner to manoeuvre for a forward quarter AIM-120 shot and, in doing so, changes his pass to slightly left-to-right. Simultaneously, Lead directs #3 and #4 to offset north-east to attack the bandit trailers on the beam, essentially bracketing the bandit formation. Lead advises he will attempt to engage both leaders in their right forward quarter with AMRAAM and will egress away from #3 and #4 to round-up, post attack, at the FAOR datum, ANGELS 11.

BULMER listens intently to the intercept progress, is now able to confirm radar contact on the bandits and advises NE is green, post-attack. STAG #3 and #4 are able to sort and target the trailing bandit element and manoeuvre with sufficient offset for an attack from the bandits' left forward quarter.

At 11 nm from the lead bandit element, STAG Lead launches his first AMRAAM. He immediately commands the radar to designate the bandit lead element wingman as the L&S target. While jinking away from the bandits, STAG Lead launches his second AMRAAM, immediately pumping to the south-west while deploying multiple bundles of chaff. STAG Lead egresses south-west but his RWR shows him targeted with semi-active radar missiles in flight. At the time of STAG Lead's first missile launch, STAG #4 advises a trailing bandit hard 'G' spike into his pair. This is confirmed by his element lead (#3) and, together, at 12 nm from their respective targets they launch AIM-120. STAG #3 and #4 pump south-east, dispensing chaff during the egress. BULMER is unable to confirm whether all four bandits have been splashed. STAG Lead's RWR has gone quiet but he is anxious to regain mutual support with his wingmen. After a few minutes, just as the 3-ship round-ups at the FAOR datum, BULMER advises the adjacent F-3 FAOR, on common frequency, of a possible bandit leaker entering their FAOR. BULMER gives DART flight a snap vector to engage the surviving bandit. The time is 2025Z.

STAG resumes counter-rotating CAP at FAOR datum. For the next several rotations, with the exception of monitoring the R/T and the engagement in the adjacent FAOR (on radar, during CAP turns), STAG maintains radio silence and searches for radar contacts. At 2038Z, two elements of aircraft, separated by 4 nm, are radar observed to transit the FAOR at low level, on an LLTR, at a G/S of 360 Kts. STAG does not engage these aircraft, as they are adhering to airspace control measures on the LLTR. They are subsequently IFF interrogated as friendly.

At 2045Z the weather deteriorates somewhat at STAG FAOR sanctuary altitudes, ANGELS 11 – 12. At 2048Z during STAG #3 and #4's hot leg, shortly after LINK 16 goes BENT, BULMER gives a snap vector to pop-up radar contacts approaching the FAOR boundary from the north. BULMER advises two bogeys, fast and on-the-deck. STAG #3 and #4 immediately commit out of the CAP, accelerating to 500 KCAS and descending in an attempt to find clear air. STAG Lead falls into 5 nm radar trail and offsets slightly to the east. STAG #4 occasionally **BUDDY-SPIKES** #3 in an attempt to maintain tactical formation integrity, in the deteriorating weather and loss of DOLLY. #3 gives a quick BRAA report, indicating a slightly cold intercept, right-to-left, with two targets on-the-deck at .9 IMN. #3 is unable to interrogate the targets. #4 calls radar tied and advises he is unable to acquire the bogeys. At a range of 12 nm #3's radar shows the bogeys turning hard into his formation. Almost immediately, #4 calls **PINNACLE, PINNACLE** and immediately pumps to egress south-east, deploying multiple bundles of chaff. #3 quickly designates one of the bogeys, launches his last AMRAAM and he, too, egresses south-east calling a **HEADS-UP, LEAKER** to STAG lead. STAG lead advises contact, sorted and clean, and elects to engage the leaker. At

10 nm he observes one radar contact disappearing off his scope and immediately locks and shoots an AIM-7M at the remaining bandit. STAG lead F-Poles to the north-east, expending chaff and further descending to area safe altitude. At TTG zero, STAG lead reverses back to CAP datum, calling for round-up and formation **STATUS**.

BULMER advises both bogeys splashed. STAG rounds-up at FAOR datum at 2053Z. Lead calls established in the counter-rotating CAP, with 15 minutes play-time. BULMER acknowledges and advises getting Return-To-Base (**RTB**) clearance for the tasked diversion base, **VICTOR**.

### 5.4.11 Recovery to Operating Base

At 2105Z, BULMER issues clearance for STAG to depart the FAOR, direct routing to the recovery aerodrome outer approach beacon, descending ANGELS 6 and contacting Victor surveillance radar on TAD 26. STAG Lead acknowledges, asks his formation for final fuel and ammo states and directs #3 and #4 to assume 3 nm radar trail. Once #3 calls tied (with #4 in close formation), Lead commences descent and routes directly to Victor outer marker, using EGI and MMD.

On check-in with Victor STAG Lead is asked to authenticate, change IFF codes and squawk IDENT. He is also advised that SHORAD approach procedures to runway 11 are in effect, that navigation approach aids are out and that flight traffic advisory to commencement of the SHORAD approach, only, would be provided. Airfield altimeter is 29.74 and weather has deteriorated to a surface visibility of 1 nm and a ceiling of 300 feet AGL. At this notification, STAG requests the status of the pre-planned mission diversion base but is informed that the diversion aerodrome is not usable for reasons other than cloud or visibility minima. STAG is directed to land at Victor.

Midway during the transit to join the SHORAD approach at Victor, STAG acquires radar contact on a base defence CAP established to the north of Victor aerodrome. He requests a course deviation to avoid the CAP and is directed to set heading 225° and expedite descent to 2,000 feet MSL. As the 3-ship passes the CAP it is buddy-spiked momentarily. Once clear of the CAP, STAG is cleared own navigation to the complete the SHORAD approach.

STAG offsets his radar trail formation to join the runway centerline at 45°, 15 nm back, in accordance with the SHORAD approach procedure. Lead establishes this intercept, slows to 300 KCAS and switches the 3-ship over to **GAMBIT** operations to give status reports. STAG is informed that the MOS is 6,000 feet, commencing at the runway 4-bar extending to the high-speed cut-off.

During the 45° base leg to join the centerline at 15 nm back, STAG Lead and #3 radar designate the runway centerline, adjacent the eighth runway light down from the approach end, corresponding to the approximate 4-bar position, as their intended touchdown points. Lead and #3 select Expand 3 Doppler Beam Sharpening (**DBS**) radar mode. As the radar builds on the designation, Lead and #3 sweeten the intended touchdown point/designation. The designation is corroborated by EGI and MMD. At 15 nm back Lead joins the runway centerline and slows the (radar trail) formation to 250 KCAS at 1500 feet AGL. At this point Lead and #3 (with #4 in close formation) fly independent, radar-designated, SHORAD approaches to short final and landing. At 7 nm back they extend landing gear and land flap, set the radar altimeter to 150 feet AGL, and fly a 2 1/2° glidepath to their point of radar designation. At 200 feet AGL, the CF-18s break out of cloud and execute uneventful full stop landing. The time is 2115Z.

The CF-18s taxi in for de-arming and are shut down in designated parking in assigned HASs. Post shut-down, the aircrew debrief the recovery and turn-around crews and proceed to operations area for aircraft sign-in and full mission debrief. The composite mission scenario tasking is deemed concluded and the mission an over-all success.

# Annex 2

# Knowledge Representation Templates and Examples

# Annex 2: KNOWLEDGE REPRESENTATION TEMPLATES AND EXAMPLES

The following include templates and examples of how knowledge is represented that serves in tracking pilot actions, plans and goals. This document has been constructed to describe a particular Composite Mission Scenario (CMS) that was used in the current IAI contract. Although the representational templates and examples are complete relative to the current contract, they should be viewed as evolving and incomplete until they have been tested in a completed CF-18 simulation environment.

Acronyms

General Rule(s):

(<acronym>, <meaning>, ACRONYM)

Example(s):

(JFC, Joint-Force-Cdr, ACRONYM)
(ACO, Airspace Coordination Order, ACRONYM)

Activities

General Rule(s):

- (<characterisation>, <A#>, EQUAL) | (<A#>, C#, CAUSE-OF) | (T#, A#, EQUAL)
  [where, C# = Cause#; T# = Tasking#]

<A#> = <Activity #>

- (<object>, <subject>, <verb> | <combination verb>)
- (<intent>)
- (<effect>, <cause>, CAUSE-OF)
  - (effect = <A#> = <activity>)
  - (cause = <C#> = <cause>)
- (<[Implied Unspecified]>, <A#>, <verb> | <combination verb>)
- ((<T#> & <T#> & <>…), <subject>, CONTAINS)
  - (T#, Task #, EQUAL)

Example(s):

  - (Petition, A1, EQUAL)

A1:

- (UN, Country (Z) PETITIONED-TO-ACT)
  - (Petition, A1, EQUAL)
- To intervene with action appropriate to bring the hostile parties ((Country (X) & Country (Y) & Extremist Groups (E)) to a negotiated settlement including goals:

----

(A2, C1, CAUSE-OF)

A2:
(Country (C), Deploy-Armed-Forces, Country (Z), REQUEST-OF-TO)

----
- (EnforcementFlights, A3, EQUAL)

A3: (Activity)
- (A3, CF-18s, CONDUCTED-BY)
    - (Perimeter (Northern-Provinces(Country (Z)), LOC)
    - (Past-Two-Weeks, WHEN)

----
- (Air-Campaign, A4, EQUAL)

A4: (Activity)
- ([Implied Unspecified], A4, DEVELOPED-BY) &
- ([Implied, Unspecified], A4, BEING-IMPLEMENTED-BY)

----
- (Offensive-Air-Activity, A5, EQUAL)

A5: (Activity)
- (Coalition (Z), Offensive-Air-Activity, COMMENCED-BY)

----
- (T1, A6, EQUAL)
- (A6, GS1, EQUAL)

A6: (Activity)
GS1a:
- To conduct a Combined Allied Military Air Operation (CAMAO) Route Sweep FOR a package of 8 UK Tornado GR-1 ground attack aircraft
    - Pursuer(s): CF-18s (Country (C))

----
A7: (Activity)
GS2a

----
A8: (Activity)
GS3a

Allegations
General Rule(s):

- (AL#, P#, EQUAL) - Proposition (P#) is the same as an Allegation (AL#)

Example(s):

- (AL#1, P1, EQUAL) - Proposition (P1) is the same as an Allegation (AL#1)

Causation

General Rule(s):

- (F#, (F# & A#), CAUSE-OF) - PASSV

- (E#, <characterisation>, REASON-FOR)
- (CAUSE-OF, REASON-FOR, PARA) - see paraphrases, below.

Example(s):

- (F2, (F500& AL1), CAUSE-OF)

- (E2, Safety & Security, REASON-FOR)
- (CAUSE-OF, REASON-FOR, PARA)

Counting

General Rule(s):

- (<characterisation>, <object>, NUMBER-OF)

Example(s):

  - (Considerable Number, Refugees, NUMBER-OF)

Crisis

General Rule(s):

- (CRISIS, C#, EQUAL)

Example(s):

- (CRISIS, C1, EQUAL)
  - (CR1a & CR1b, CR1, EQUAl)

CR1a: (Crisis)

- (Regional-Military-Alliance, ((Country (X) & Country (Y)), Extremist Groups (E)), EXIST-BETWEEN)
  - (Northern-Provinces (Z), Extremist Groups (E), LOC)

CR1b: (Crisis)

- (Air-and-Sea-Embargo, Country (Y), Country (Z), PLACED-WHAT-ON) & (Ground-Forces (Z), Perimeter (Northern-Provinces(Z)), Country (Z), POSITIONED-WHAT-ALONG) & (Flow of People & Materials, Northern-Provinces(Z), Country (Z), HALTED-WHAT-INTO)

Deployment

General Rule(s):
- (D#, <object>, AGREED-TO)

Example(s):
- (D1, Country (C), AGREED-TO)

D1: (Deployment)
    - (Deployment, Squadron-of-Reaction-Force-CF-18s (Canada), EQUAL)
    - (AGREEMENT, D1, PARA)

Equality

General Rule(s):
- (<object#>, <object#>, A EQUALS)

Example(s):
- (P1, A1, EQUALS)
- (CRISIS, C1, EQUALS)
- (Provisional-Government (Z), Extremist Groups (E) & Elements-Of-Armed-forces (Country (X) & Country (Y)), EQUALS)

Events

General Rule(s):

<E#> = <Event #>
- (<E#>, <characterization>, PARA)
    - (PARA = <paraphrase>)

Example(s):
- (E1, (Country (X) & County (Z)), HAVE-OCCURRED)
    - (E1, CLASHES, PARA)
    - (alarming-rate, E1, FREQUENCY-OF)

E1: Events

E1a: (FishingVessels (Country (Z), Country (X), BOARD) &
E1b: (FishingVessels (Country (Z), Country (X), SEIZE) &
E1c: (FishingVessels (Country (X), Country (Z), BOARD) &
E1d: (FishingVessels (Country (X), Country (Z), SEIZE)

E2: (Event(s))
- (Northern-Provinces, Refugees, LEFT)
    - (Considerable-Number, Refugees, NUMBER-OF)
    - (Governing-Body (Z), Refugees, SYMPATHETIC-TO)

E3
- (Northern-Provinces (Z), Components-of-Military-Forces ((Country (X) & Country (Y)), TAKEN-FOOTHOLD)

- (E3, INVITATION-TO-BY(ITB1), CAUSE-OF)

Facts

General Rules:

- (<proposition#>, <object> | <object>, <object>, VERB | COMBINATION- VERB)
- (<object>, R#, VERB | COMBINATION- VERB)
  [where R# = Relationship#)

F1: (Fact)

- (P1, Country (X), CLAIMS)

F2: (Fact)

- (GoverningBodies (Country (X) & County (Z)), R1, EXIST-BETWEEN)

R1:

- ("chilled" (R2), R1, KIND-OF)
- (considerably, R1, EXTENT-OF)

R2:

  - ("indifferent", R2, KIND-OF)
  - ("Decades-Long", R2, DURATION-OF)

Frequency

General Rules:

- (<characterization>, E#, FREQUENCY-OF)

Examples:

  - (alarming-rate, E1, FREQUENCY-OF)

Goals (Intents) & GoalSets (IntentSets)

[Note: Goals are expressed as intents (preceded by the word, "to")]

General Rules:

- G#: (Goals)
- To <characterization> | <characterization> & <characterization> …
  - Pursuer(s): <pursuer> | < pursuer > & < pursuer > & …
- (<Goal-Set #>, GS#, EQUAL)
- ((GS#l,…GS#l), GS #, CONTAINS)

Examples:

- (Goal-Set #1, GS1, EQUAL)
- ((GS1a,…GS1c), Goal-Set #1, CONTAINS)

GS1a:

- To conduct a Combined Allied Military Air Operation (CAMAO) Route Sweep FOR a package of 8 UK Tornado GR-1 ground attack aircraft

GS2a

- To re-commit to new tasking
  - To protect High Value Airborne Asset (HVAA);

GS3a

- To re-commit to new tasking
  - To establish (base defence) FAOR;

O1: (Operations)

- (Operations, G1, GOAL-OF) - PLURAL

G1: (Goals)

- To re-establish Zardian Rule of law on Northern Provinces (Z) &
- To assist in the eviction of ArmedForces (Country (X) & Country (Y) & Extremist Groups (E))
  - (Canada, Country (C), EQUALS)

G2:

- To provide a multi-role war fighting capability
  - (TaskGoal, G2, KIND-OF)

Location

General Rules:

- Location is indicated in a variety of ways and specified by LOC.
- (<object>, <object>, LOC)

Examples:

- (Northern Provinces (Z), Extremist Factions (E), LOC) - the extremist factions are located in the northern provinces.
- (OilReserves, (Seabed, DFFG, BELOW) LOC) - the oil reserves are located in the seabed below the DFFG.

Objects

General Rules:

- <object> (<name>)

Examples:

- Country (X)
- New Territorial Limit (L)
- Northern Provinces (Z)

Object Attributes

General Rules:

- <object> (<name>)

Examples:

- Content (D) = "Content of Disputes"
  (Content (D), "Boundary", EQUAL)
  (Components-of-Military-Forces ((Country (X) & Country (Y)), WELL-EQUIPPED) &
  (Components-of-Military-Forces ((Country (X) & Country (Y)), ARMED)

Operations

General Rules:

[Note: A complex activity that should be incorporated into the representation of activities.]

- (Operations,, A#, VERB)
  [where A# is Activity#]

  Examples:
- (Operations (O1), A2, SUPPORT)

O1: (Operations)
- (Operations, G1, GOAL-OF) - PLURAL

Paraphrase

General Rules:
- (<word | concept>, <word | concept>, PARA)

Examples:
- (ENCOMPASSES, CONTAINS, PARA)
- (E1, CLASHES, EQUAL)
  [where E# is Event#]
- (E1, INCIDENTS, PARA)
- (FORMED, ESTABLISHED-BETWEEN, PARA)
- (CAUSE-OF, REASON-FOR, PARA)
- (Naval & Air & Ground, FORCES, INCLUDE)

Propositions

General Rules:
- (<P#>, <object>, <verb> | <verb combination>)
- (<proposition>, object, <verb> | <verb combination>)

Examples:

[(P1, Country (X), CLAIMS)]

P1:
  - (OilReserves, Country (Z), HAS-DISCOVERED)
    - (OilReserves, (Seabed, DFFG, BELOW) LOC)

- DISPUTES (D) [This will be a list of disputes]

Pursuer(s)

General Rules:
- <"Pursuer(s):">, <object>

Examples:
- Pursuer(s): four-aircraft flight of CF-18s (Country (C))

Qualifiers
- of Verbs
  - ONLY WHEN
    Ex: Intent is "To introduce"; only when represented as (necessary to ensure all relevant issues are included during mission execution, ONLY WHEN)
  - HOW
    Ex. Verb is "DECLARED"; how is "(unilaterally, V1, HOW)"

- of Nouns
    - KIND-OF
      Examples:
      (Linked, TA, KIND-OF), where TA = Terrorist Acts (TA)
      (Indifferent, Relations, KIND-OF)

    - DURATION-OF
      Examples:
      (Decades-Long, R1, DURATION-OF)

    - EXTENT-OF
      Examples:
      (considerably, R1, EXTENT-OF)
      (Enormous, Upheaval & Instability, EXTENT-OF)

Relationship(s) & Relation(s)

General Rules:

R#: (Relationship)
- (<characterisation>, R#, VERB | VERB-COMBINATION)

Examples:

F2: (Fact)
- (GoverningBody (Country (X) & GoverningBody (County (Z)), R1, EXIST-BETWEEN)

R2: (Relationship)
- ("indifferent", R2, KIND-OF)
- ("Decades-Long", R2, DURATION-OF)

States

General Rules:

S#: (State)
- (S#, <object>, VERB)

Examples:
- (S1, E1, CAUSE-OF)

State Sets

General Rules:
- (SS#, S#, EQUALS)
- (SS#a & SS#b & …& SS#z), SS#, EQUALS)

SS#: (State-Set)

(<characterisation>, S#a, EQUALS)

Examples:
- (SS1, S1, EQUALS)

- (SS1a & SS1b, SS1, EQUALS)

SS1: (State-Set)
("Upheaval", S1a, EQUALS) &
("Instability", S1b, EQUALS)

Examples:

- Pursuer(s): four-aircraft flight of CF-18s (Country (C))
- STATE-OF
  Examples:
  (Civil-Authority (Z), COLLAPSE, STATE-OF)
  (Diplomacy-&-Mediation-Efforts, FAILED, STATE-OF)
  (Negotiations (N1), COLLAPSE, STATE-OF)
  (ACO, IN-EFFECT, STATE-OF)

Tasking(s)

- ((T1 & T2 & T3), CM, CONTAINS)
- (Tasking, (T1 & T2 & T3), INSTANCES-OF)
- (Tasking, T1, EQUAL)

Time

- Examples:
  Time (February 2000)

Threats

General Rules

- (<Threat-Set (Mission)>, <subject>, <verb>)

- Examples:
  (THS (M),Intelligence-Data, IDENTIFIES)
  (THS (M), Threat-Set (Mission), EQUAL)

Verbs

- DECLARE (V1) - PAST

Number

We will preserve number in the narrative and in future look for ways to simplify it.

- Singular; Plural
  Examples:
  (E1, Clashes, ARE) - PLURAL

Tense

We will preserve the tense in the narrative and in future look for ways to simplify it.

- Present, Past, Present Perfect, Past Perfect, etc.
  Examples:

Voice

The use of voice determines the order in which items appear in the pseudo code. We will use active voice, not passive in representations but we could have a flag for when passive voice is used in the narrative and have a way of converting active to passive voice, if required.

- Active vs Passive
  Examples:
  - CAUSES vs CAUSED

Verb Combinations

- BOLSTERED-BY
  Examples:
  (Provisional-Government (Z), Elements-Of-Armed-forces (Country (X) & Country (Y)), BOLSTERED-BY)

- COMMITTED-BY
  Examples:
  (Extremist Factions (E), TerrorActs (TA), COMMITTED-BY)

- ESTABLISHED-BY
  Examples:
  (XEFZ, Country (X), ESTABLISHED-BY)

- EXIST-AMONG
  Examples:
  (Near Panic, Countries (Neighbouring), EXIST-AMONG)
  (Provisional-Government (Z) Country (Z) & (UN), N1, EXIST-AMONG)

- EXIST-AT
  Examples:
  (Great-Concern, UN, EXIST-AT)

- EXIST-BETWEEN
  Examples:
  (Chilled-Relations, County (X), County (Z), EXIST-BETWEEN)

- EXIST-UNDER
  Examples:
  (UN Charter, Diplomacy-&-Mediation-Efforts, EXIST-UNDER)

- HAS-DISCOVERED
  Examples:
  (OilReserves, Country (Z), HAS-DISCOVERED)

- HALTED-WHAT-INTO
  Examples:

(Flow of People & Materials, Northern-Provinces(Z), Country (Z), HALTED-WHAT-INTO)

- IMPOSED-BY
  Examples:
  (Martial-Law, Extremist Factions (E), IMPOSED-BY)

- INVITATION-TO-BY
  Examples:
  (Components-of-Military-Forces ((Country (X) & Country (Y)), Leadership (E)), INVITATION-TO-BY)

- LAID-SIEGE
  Examples:
  (Installations, Extremist Factions (E), LAID-SIEGE)

- PLACED-WHAT-ON
  Examples:
  (Air-and-Sea-Embargo, Country (Y), Country (Z), PLACED-WHAT-ON)

- POSITIONED-WHAT-ALONG
  Examples:
  (Ground-Forces (Z), Perimeter (Northern-Provinces(Z)), Country (Z), POSITIONED-WHAT-ALONG)

# Annex 3

# Knowledge Representation in the Composite Mission Scenario

# Annex 3: REPRESENTATIONS OF KNOWLEDGE IN THE COMPOSITE MISSION SCENARIO

The following is a draft representation of the wide variety of information contained in the Composite Mission Scenario (CMS) of the CF188 APG-65 Radar Human Factors Engineering Study Mission Analysis Report prepared by BAE Systems Canada Inc. (2000). The material contains representations for all of the explicit information contained in the 20-page description and much of what is implied. Natural language descriptions are notorious for their implications, for their sometimes ambiguous referents, for ellipsis and a wide variety of natural language phenomena that make it difficult to represent its complete meaning.

In contrast, one advantage to composite mission scenarios is that they conform to the various rules of engagement and seek to make explicit much of what a pilot will encounter. Such scenarios often are constructed with simulations in mind and so serve to encourage writers to make things more explicit than they might otherwise do.

A number of caveats were identified in the body of the paper in introducing this Annex and the reader is referred again to those. Future work will refine and extend the following representations, specify how the knowledge represented is to be decomposed and distributed among various EMD models to support intelligent, adaptive aiding and describe how the knowledge will be used in inference.

The analysis which follows is presented in a way that should make it easy to follow in the write-up of the CMS. Sections and page numbers are identified to help in the process. The page numbers

**Page 5.1 (39)**

## 5.1 INTRODUCTION

### I. High-Level Contextual Goals

A number of high-level contextual goals stand outside of the goals of the actual mission. First, there are *rules that constrain the CMS* and as such govern its preparation

Purpose of CMS and CMS Document
- To provide APG-65 Radar Project team members with a baseline document that describes the key elements, implied requirements and essential system functions;
- To develop the Operational Sequence Diagrams (OSDs);
- To [eventually] serve as a reference during the production of the rapid prototype interface design for the APG-65 Radar distributed simulation;
- To reflect the employment of the CF-18 in the air-to-air/Counter Air Operations role
- To serve as a means to ensure that all top-level functions associated with the APG-65 Human Factors Engineering (HFE) study are identified;
    - To report the functional decomposition of the top-level functions separately in a Function Analysis Report

Purposes of using a composite CF-18 multi-task air-to-air role scenario
- To focus the analysis on mission sequences that are particularly demanding from a workload perspective, or are likely to be critical to requirements definition and the eventual design of the user interface;
- To avoid wasting effort by analyzing functions that have already been analyzed, are unlikely to be critical to overall system performance, or are unlikely to provide any added value.

- To write the scenario as a straightforward narrative
    - To provide for authenticity in the CMS document
        - To use some terms unfamiliar to the non-fighter pilot user
        - To hilighte those terms and
        - To define their meaning in Annex A
    - To introduce artificialities into the overall mission description
        - (necessary to ensure all relevant issues are included during mission execution, ONLY WHEN)

Rules governing preparation of the composite scenario:
- To specify one and only one top-level mission function;
- To determine mission duration using the following factors:
    - [not specified]
    - To determine influence on mission execution of factors:
        - aircraft fuel;
        - ammunition loads.

    [UNSPECIFIED: relation of mission duration to mission execution]
- To re-locate forces in time and/or space;

- To replenish weapon loads and fuel as necessary.

**Comments:** As with many of the goals in the CMS narrative, the above will require elaboration and clarification. Representation is needed for **endogenous and exogenous states (conditions and events)** in various parts of the CMS. *Endogenous states* are those determined by actions of humans or other agents; *exogenous states* are those determined by external factors such as weather.]

### 5.2 AIM & SITUATION

II. Other contextual goals

Overall goal of the CMS:

- *To portray the planning and execution of the CF-18 air-to-air operation*

Related contextual goals:

- To focus on the tactical application of air operations solely;
  - [NOT] To focus on overarching strategic objectives;

**Page 5.2 (40)**

- To integrate the air power capabilities of several different nations and services;
- To exploit the capabilities and roles of the CF-18 [context: CF-18 limitations];
  - To identify the limitations of the CF-18;
- To incorporate an all weather/night aspect to the overall mission profile/taskings;
- To base the operation [planning & execution] on realistic CF-18 operational training and aircrew proficiency levels;
  - To identify operational training and aircrew proficiency levels.
- To require [necessitate] positive identification in the air when called for by scenario ROE;
  [meaning??]
- To use a single ATO for the air to air operation that is easily disseminated by a Tactical Air Operations Centre (TAOC);
- To rely on comprehensive, timely, accurate and current intelligence which is air focused.

### 5.3 SITUATION

In addition to *GOALS* (stated above as intentions), *factual elements (STATES)* form part of the context of the mission. Those elements are specified by date in the CMS and examples can be represented by declarative information, including satisfied (failed; abandoned; suspended) goals.

Seven time frames are identified and their representations may be expressed as in the first of those as follows:

*A. Time Frame #1*

- TimeNOW (November 1999)
- (Country (C), Canada, EQUAL)
- (Country (X), Xar, EQUAL)
- (Country (Y), Yar, EQUAL)

- (Country (Z), Zar, EQUAL)
- To illustrate the political situation in Figure 5-1

The second goal below is instrumental in accomplishing a number of higher level goals whose content and relationships may be expressed as follows:

- To sustain X's economy
    - To sell fish abroad &
    - To provide X with a critical food supply
        - To protect X's access to the Deep Fathom Fishing Grounds (DFFG) &
        - To protect X's Sea Lines of Communication (SLOC)
            - To [effectively] move the X's territorial waters out to 300 nm [From x nm].
                - To declare a Xarian Economic Fishing Zone (XEFZ)
                    - Pursuer: Government of Country (X)

Other facts include:
(New Territorial Limit (NTL), Country (X), DECLARE (V1)) - PAST

- (unilaterally, V1, HOW)
- (November, 1999, V1, WHEN)

(Country (Y), New Territorial Limit (NTL), "ENCOMPASSES")

- (X, Y, ADJACENT-TO) &
- (X, Y, NEIGHBOUR-OF) &
- (X, Y, SYMPATHETIC-TO)
- (Y, Island, IS)
- (CONTAINS, "ENCOMPASSES," PARA)

(Territorial Waters (Z), New Territorial Limit (NTL), ENCROACH-ON)
    (12nm, Territorial Waters (Z), EQUAL)

(Disputes (D), Extremist Factions (E), Country (Z), HAS-HAD-WITH)
    (Boundary (B), Disputes (D), TYPE-OF)
        (Internal, Boundary (B), TYPE-OF)
        (Northern Provinces (Country (Z)), Extremist Factions (E), LOC)

(Extremist Factions (E), TerrorActs (TA), COMMITTED-BY)
    (linked, TerrorActs (TA), TYPE-OF)
    ((TerrorActs, Perceived Ethnic Persecution, CAUSE-OF) &
    (TerrorActs, Perceived Religious Persecution, CAUSE-OF))

*B. Time Frame #2*

- TimeNOW (January 2000)

IN: (INFORM)

- (P1, Country (X), CLAIM) - PPERFECT
  (INFORM, "Allegation," PARA)
  (INFORM, Allegation, TYPE-OF)

PP: (Proposition)

  - (OilReserves, Country (Z), DISCOVER) - PPERFECT
    - (OilReserves, (DFFG, Seabed, BELOW) LOC)

(FT2, (F200 & AL1), CAUSE-OF)

FT2: (Fact)

- (GoverningBody (Country (X) & GoverningBody (County (Z)), R1, EXIST-BETWEEN)

FT200: (Fact)

- (XEFZ, Country (X), ESTABLISHMENT-OF) - PASSV
  Time (November, 1999)

AL1: Allegation #1

- (INFORM, Allegation, TYPE-OF)

RL1: (Relationship)

- ("chilled" (R2), R1, EQUAL)
- (R1, "considerable," EXTENT-OF)

RL2: (Relationship)

  - (("indifferent" & "Decades-Long")), R2, EQUAL)

- (EV1-PLURAL, (Country (X) & County (Z)), OCCUR) - PTPERFECT
  - ("CLASHES ," E1, PARA)
  - ("INCIDENTS ," E1, PARA)
  - (alarming-rate, E1, FREQUENCY-OF)

EV1-PLURAL: EVENTS

  - ((EV1a & EV1b & EV1c & EV1d), EV1-PLURAL, EQUAL)
    EV1a: (Country (X), FishingVessels (Country (Z), BOARD) &
    EV1b: (Country (X), FishingVessels (Country (Z), SEIZE) &
    EV1c: (Country (Z), FishingVessels (Country (X), BOARD) &
    EV1d: (Country (Z), FishingVessels (Country (X), SEIZE)

- (ST1-PLURAL, EV1-PLURAL, CAUSE-OF)
  - (Enormous, ST1-PLURAL, EXTENT-OF)
  - (Recent-Months, ST1-PLURAL, WHEN)

  - (Region, ST1-PLURAL, LOC)

- ((ST1a & ST1b & ST1c & ST1d), ST1-PLURAL, EQUALS)
  ST1a : ("Upheaval", S1a, EQUALS) &
  ST1b: ("Instability", S1b, EQUALS)
  ST1c: (Near Panic, Countries (NEIGHBOURING), EXIST-AMONG)
    - ("NEIGHBOURING," ADJACENT-TO, PARA)

  ST1b: (Great-Concern, UN, EXIST-AT)

**Page 5.3 (41)**

*C. Time Frame #3*
(PG 5.3, PARA 1, SN 1)
- TimeNOW (February 2000)

(PG 5.3, PARA 1, SN 2)
- ((Security-Coalition, ((Country (X) & Country (Z)), ESTABLISH-BETWEEN) – PPERFECT &
  - ("formed," ESTABLISH-BETWEEN – PPERFECT, PARA)

(PG 5.3, PARA 1, SN 3)
(Provincial-Government (PG), Extremist Factions (E), OUSTED) – PPERFECT &
  - (Northern-Provinces, Extremist Factions (E), LOC)
  - TimeNOW ("at the same time")

(Installations, Extremist Factions (E), LAID-SIEGE) – PPERFECT &
  - (Installations, Northern-Provinces, LOC)
  - ("all major," Installations, TYPE-OF)

(PG 5.3, PARA 1, SN 4)
(Civil-Authority (Z), COLLAPSED) – PPERFECT &
  - ("All", Civil-Authority (Z), TYPE-OF)

(STATE-OF (Martial-Law), Provinces, UNDER )
  - (STATE-OF (Martial-Law), Extremist Factions (E), IMPOSE) – PASSV

(PG 5.3, PARA 1, SN 5)
EV: (Event)
- (Northern-Provinces (LOC), Refugees, LEFT) – PPERFECT
  - ("Considerable-Number", Refugees, NUMBER-OF)
  - (Governing-Body (Z), Refugees, SYMPATHETIC-TO)

  - (Safety & Security, E2, REASON-FOR)
  - (CAUSE-OF, REASON-FOR, PARA)

(PG 5.3, PARA 2, SN 1)
D. Time Frame #4
- TimeNOW (March 2000)

[CHARACTERISATION – (APPEARS LATER IN CMS (PG 5.4, PARA 1, SN 1)]
- (CRISIS, CR1, EQUAL)
- (CR1a & CR1b, CR1, EQUAl)

(PG 5.3, PARA 2, SN 2)
CR1a: (Crisis)
- ((Country (X) & Country (Y) & Extremist Groups (E)), Regional-Military-Alliance, STRUCK-BETWEEN) – PPERFECT & PASSV
  - (Northern-Provinces (Z), Extremist Groups (E), LOC)

(PG 5.3, PARA 2, SN 3)
EV (Event)
- (FOOTHOLD, Components-of-Military-Forces ((Country (X) & Country (Y)), TAKE) - PPERFECT
  - (Northern-Provinces (Z), FOOTHOLD, LOC)
- (E3, INVITATION-TO-BY (ITB1), CAUSE-OF)

ITB (INVITATION-TO-BY)
  - (Components-of-Military-Forces ((Country (X) & Country (Y)), (Leadership (Extremist Groups (E)), INVITATION-TO-BY)
    - (WELL-EQUIPPED, Components-of-Military-Forces ((Country (X) & Country (Y)), STATE-OF) &
    - (ARMED, Components-of-Military-Forces ((Country (X) & Country (Y)), STATE-OF)

- (E4, Diplomacy-&-Mediation-Efforts, INCLUDE)

(PG 5.3, PARA 2, SN 4)
TimeNOW
[WHILE (NOT-EXIST, CredibleThreat-of-Deliberate-Military-Attack, STATE)
  - ((Outside (Northern Provinces (Country (Z)), LOC)]

E (Event)
- (UN, A1, Country (Z), PETITION-AGENT-TO) - PPERFECT
  - (Petition, A1, EQUAL)
  - ("Petition", REQUEST, PARA)

AC: (Activity)

  - To intervene with action appropriate to bring the hostile parties ((Country (X) & Country (Y) & Extremist Groups (E)) to a negotiated settlement including goals:
    - GL: To leave sovereign territory (Country (Z))
      - Pursuer(s): Country (X) & Country (Y) & Extremist Groups (E)
    - GL: To re-establish the provincial authority and sovereign rule
      - Pursuer(s): Country (Z) & UN
  - Pursuer(s) (AC1): UN

(PG 5.3-5.4, PARA 2, SN 5)

- (FAILED, Diplomacy-&-Mediation-Efforts, STATE-OF)
  - (UN Charter, Diplomacy-&-Mediation-Efforts, EXIST-UNDER)

(PG 5.3-5.4, PARA 2, SN 5)

- (GL, COLLAPSE) – PPERFECT
  - To negotiate with Provisional-Government (Z)
    - (Provisional-Government (Z), Elements-Of-Armed-forces (Country (X) & Country (Y)), BOLSTERED-BY)
    - (Provisional-Government (Z), Extremist Groups (E) & Elements-Of-Armed-forces (Country (X) & Country (Y)), EQUAL)

**Page 5.4 (42)**

*E. Time Frame #5*

(PG 5.4, PARA 1, SN 1)

- TimeNOW (April 2000)

(PG 5.4, PARA 1, SN 2)

CR1b: (Crisis)

- (Air-and-Sea-Embargo, Country (Y), Country (Z), PLACED-WHAT-ON)

(PG 5.4, PARA 1, SN 3)

- (Ground-Forces (Z), Perimeter (Northern-Provinces(Z)), Country (Z), POSITIONED-WHAT-ALONG) – PPERFECT &
  (Flow of People & Materials, Northern-Provinces(Z), Country (Z), HALTED-WHAT-INTO) – PPERFECT

(PG 5.4, PARA 2, SN 1)

(A2, C1, CAUSE-OF)

A2: (Activity)

- (Country (C), GL1a, Country (Z), REQUEST-OF-TO)
    - (Canada, Country (C), EQUAL)

GL1a (Goal)

- To deploy armed forces
  (G1b, GL1a, INSTRUMENTAL-IN)

GL1b (Goal)

- To support operations
  (G1c, GL1b, INSTRUMENTAL-IN)

GL1c (Goal)

- To re-establish Zardian Rule of law &
    - (Northern Provinces (Z), LOC)
- To assist in the GL1d

GL1d (Goal)

- To evict ArmedForces (Country (X) & Country (Y) & Extremist Groups (E))

(PG 5.4, PARA 2, SN 2)

AG (Agreement)

- (PL (GL1), Country (C), AGREED-TO)
    - (AG (Country (C) & Country (Z)), Bilateral-Security-Alliance, CAUSE-OF)

PL (GL1): (Plan)

- To deploy a Squadron of its Reaction Force CF-18s
    - Pursuer(s): PL (Country (C))

(PG 5.4, PARA 2, SN 3)
AG (Agreement)
- (GL1, Nations (Unspecified), AGREED-TO)

GL1 (Goal)
- To support Country (Z)
  (G1, GL2, INSTRUMENTAL-IN)

GL2 (Goal(s))
  - to provide naval, air and ground forces
  - to provide logistics supply groups
  - to provide engineering and hospital support elements

(PG 5.4, PARA 2, SN 4)
AC (Activity)
- (Z-Coalition & (Forces (Country (X) & Country (Y) & Extremist Groups (E)), ArmedConflict, INEVITABLE-BETWEEN)

(AC, ((Deadline (Country (Z), PASS) – PPERFECT), CAUSE-OF)
  - (GL, Deadline (Z) EQUAL)
    GL (Goal)
    - to withdraw elements
    - ("Voluntary", Withdraw, HOW)
    - ("Intrusive", Elements, TYPE-OF)

*F. Time Frame #6*

(PG 5.4, PARA 3, SN 1)

- Time (May 2000)

(PG 5.4, PARA 3, SN 2)

- (Country (Z), CF-18s (Country (C)) & Elements (All Supporting), DEPLOY-TO) – PPEFECT

(PG 5.4, PARA 3, SN 3)

- (JFC, Operational-Control (CF-18s (Country (C))), CHOP-TO) – PPEFECT
  - (JFC, Joint-Force-Cdr, ACRONYM)
  - (Armed-Forces-Chief-of-Staff (Country (Z)), JFC, APPOINT-BY) - PAST

[Definition: "CHOP" - Change of Operational Control; national forces are 'chopped' to SACEUR/SACLANT etc. (also TOA (TOA - Time of Arrival))

- (EnforcementFlights, A3, EQUAL)

(PG 5.4, PARA 3, SN 3)

TimeWHEN

  - (Past-Two-Weeks, WHEN)
- (GL, CF-18s, CONDUCT) – PPERFECT-PROG

GL: (Activity)

- ("EnforcementFlights", GL, EQUAL)
- To conduct flights
  - ("along perimeter", flights, LOC)
    - (Perimeter (Northern-Provinces(Country (Z)), LOC)

*G. Time Frame #7*

(PG 5.4, PARA 4, SN 1)
- TimeNOW (0000, Zulu (**Z**))
  - (21 May 2000, Zulu (**Z**), EQUAL)

(PG 5.4, PARA 4, SN 2)
  - (Air-Campaign, DEVELOP) – PPERFECT &
  - (Air-Campaign, IMPLEMENT) – PROG

  - ([Implied Unspecified], Air-Campaign, DEVELOPED-BY) &
  - ([Implied, Unspecified], Air-Campaign, BEING-IMPLEMENTED-BY)

(PG 5.4, PARA 4, SN 3)
  - (Offensive-Air-Activity (Coalition (Z)), COMMENCE) - PPERFECT

(PG 5.4, PARA 4, SN 4)
  - ( [Implied], ATO, ISSUE-BY) – PPERFECT-PASSV &
    - (ATO, Abbreviated Technical Order, ACRONYM)
  - (GL, CF-18s (Country (C), TASK-TO) – PPERFECT-PASSV

GL:
    - To provide a multi-role war fighting capability

(PG 5.4, PARA 4, SN 5)
  - (IN-EFFECT, ACO, STATE-OF)
    - (ACO, Airspace Coordination Order, ACRONYM)

## 5.4 MISSION

**[Comment:** The mission goals have been generally identified and will be elaborated shortly The highest level goal/subgoal pair identified at Time(Z) appear to be:

(PG 5.4, PARA 5, SN 1)
- To support the air campaign plan
  - To assign a CM to a four-aircraft flight of CF-18s
    - (CM, four-aircraft flight of CF-18s (Country (C), ATO, ASSIGN-WHAT-TO)
      - (CM, "Composite-Mission", ACRONYM)

(PG 5.4, PARA 5, SN 2)
The tasking of the mission may be expressed by the following information, including high-level goals, ordered in time:
- ((T1 & T2 & T3), CM, CONTAINS)
- ((T1 & T2 & T3), Tasking, INSTANCES-OF)
- (Tasking, T1, EQUAL)
- (Section-of-CF-18s (Country (C), AC, TASKED-TO)
- (T1, AC, EQUAL)
- (AC, GLS, EQUAL)
- (Goal-Set, GLS, EQUAL)
- ((GSa,...GSc), Goal-Set, CONTAINS)

AC: (Activity)

(PG 5.4, PARA 5, SN 3 (a.))
GLSa:
- To interdict a re-supply choke point on the island of Y;
  - Pursuer(s): GS1b, 8 UK Tornado GR-1 ground attack aircraft

- (GLSa, GL, INSTRUMENTAL-IN)

GL
- To conduct a Combined Allied Military Air Operation (**CAMAO**) Route Sweep for a package of 8 UK Tornado GR-1 ground attack aircraft
    - Pursuer(s): CF-18s (Country (C))

(PG 5.4, PARA 5, SN 3 (b.))
GSb:
WHEN (post Sweep mission)
- To rendezvous (RV) with a Royal Air Force (RAF) VC-10 Air-to-Air Refuelling (AAR) Tanker
  - To refuel [Implied];
    - Pursuer(s): CF-18s (Country (C))

(PG 5.4, PARA 5, SN 3 (c.))
- (Re-tasking, T2, EQUAL)
- (T2, Section-of-CF-18s (Country (C), RE-TASKED-TO)
- (T2, AC, EQUAL)
- (AC, GLS, EQUAL)
- (Goal-Set #2, GLS, EQUAL)
- ((GLSa & GLSb), Goal-Set #2, CONTAINS)

AC: (Activity)

GLSa
- To re-commit to new tasking
    - To protect High Value Airborne Asset (HVAA);
        - (AWACS, HVAA, INSTANCE-OF)
            - (AWACS, NATO E-3 Airborne Warning and Control System (AWACS), ACRONYM)
        - (Mixed Fighter Force Operations (MFFOs) with Royal Netherlands Air Force (RNAF) F-16 aircraft, GS2a, TO-INCLUDE)

GLSb
- To RV with a RAF VC-10 AAR,
    - (post HVAA mission, WHEN)

- (Re-tasking, T3, EQUAL)
- (T3, Section-of-CF-18s (Country (C), RE-TASKED-TO)
- (T3, A8, EQUAL)
- (A8, GS3, EQUAL)
- (Goal-Set #3, GS3, EQUAL)
- ((GS3a & GS3b), Goal-Set #3, CONTAINS)

**Page 5.5 (43)**

A8: (Activity)

GS3a
- To re-commit to new tasking
    - To establish (base defence) FAOR;
        - (FAOR, CAP/Fighter Area of Operational Responsibility, ACRONYM)

GS3b
- To recover to a deployment base/aerodrome (GS1f1).

- (DepartureTime (CM), 1615Z, WHEN)
- (RecoveryTime (CM), 2100Z, WHEN)
    - (DB, LOC)

- (DB, Deployment Base, ACRONYM)

- (ACM In-Effect, STATE)
  - (ACM, Air-Space-Control-Measures, ACRONYM)

- (1100Z-2300Z, ACO, VALID-FOR-TIME) &
  (WHEN, VALID-FOR-TIME, PARA)
- ([Implied], Friendly-Forces, BCA, ISSUED-BY--TO)
  - (ACO, Airspace Coordination Order, ACRONYM)
  - (BCA, Perimeter (Northern Provinces (Z), INSTANCE-OF)
  - (BCA, Border-Crossing-Authority, ACRONYM)

### 5.4.1 Threat

- (COMPLETE, Collection-&--Analysis (OPFOR), STATE-OF) &
- (AOB/GOB/EOB, Collection-&--Analysis (OPFOR), HAS-ESTABLISHED)
  - (OPFOR, Opposing Forces, ACRONYM)
    - (AOB/GOB/EOB, Air, Ground, and Electronic Orders of Battle, ACRONYM)

- (THS (M),Intelligence-Data, IDENTIFIES)
  - (THS (M), Threat-Set (Mission), EQUAL)
  - ((Air-to-Air & Surface-to-Air), THS (M), INCLUDES)
    - (THS1, Air-to-Air Threat, EQUAL)
    - (THS2, Surface-to-Air Threat, EQUAL)

THS1: (Threat-Set)
MiG-29 FULCRUM and Su-27 FLANKER employing SLOTBACK- INDIA Band, TWS, Coherent, Look-Down, Shoot-Down, Radar; AA-10 missiles (SAR and IR Variants), AA-11 IR missiles and AA-12 active radar-guided missiles.

THS2: (Threat-Set)
a fully Integrated Air Defence (IAD) System and SAM: SA-6, SA-7, SA-8, SA-11, SA-13, SA-14 and SA-16.

### 5.4.2 Planning

- To configure the flight of four CF-18s
  (Configuration, Config-Set, INCLUDES)

WHEN (ATO, 1000Z, RECEIVED)

Config-Set:
{two (330 U.S. gallon) external fuel tanks; two AIM-9M; two AIM-7M; two AIM-120; 500 Rounds 20 MM; ALR-67; ALE-39; ALQ-126B; and ALQ-162.}

Time (1030Z)
- To assign a flight lead and other formation members to the CF-18 four –ship mission tasking.

Time (1100Z)

- To commence mission tasking
  - To co-ordinate requirements and operations for the Sweep, AAR, HVAA and FAOR taskings.

Time (1330Z)

- To contact the Tornado unit &
- To co-ordinate the taskings for the Sweep tasking

Time (1400Z)

- To participate in the detailed mission planning
  - Pursuers: {all members of the CF-18 section}

Time (1450Z)

- To hold the CF-18 mission briefing

Time (1520Z)

- To don aviation life support equipment &
- To gather {mission cards; checklists; classified codes; charts; and other mission materials} &
- To get aircraft assignment &
- To review aircraft documentation
- To get aircraft signout
  - To go to squadron operation desk

**Page 5.6 (44)**

Time (1540Z)

- To perform external aircraft inspection
- To perform walkaround
- To accept aircraft
- To perform cockpit strap-in
  - To proceed out to the restricted area of the aerodrome &

### 5.4.3 Start and Taxi

Time (1550Z)

- To start aircraft
- To program mission critical data into the EGI
  (EGI, Embedded Global Positioning/Inertial Navigation System, ACRONYM)
- To complete weapons system checks [completed without incident]
- To call for formation status check-in
- To request taxi

Time (1610Z)

- To clear to taxi
- To user most expeditious routing [TO: taxiway FROM: [current position]
    - To taxi to the active runway &
    - To stagger with a minimum interval of 200 feet spacing on taxiway &
    - To line up for departure

### 5.4.4 Take-off and Climb

- To line up as 2 plus one plus one
- To line up 2000 feet down the runway &
- To line up offset to downwind &
- To line up with #2 on the upwind side of lead &
- To line up on the upwind side of lead &
- To line up with #2 slightly forward of lead's tailpipes
    - Mutual Pursuer(s): section lead & #2

(Lateral separation (lead, #2), directional control problems, no risk of collision on runway, takeoff roll (EVENT))

- To line up to upwind side of lead's formation &
- To line up at the button of the runway &
    - Mutual Pursuer(s): #3 & #4

Time (1615Z)

- To authorise take-off
    - To request take-off
        - Pursuer(s): section lead
        - To call "ready"
        - Pursuer(s): #4
        - (All aircraft in position, STATE) &
        - All pre-take-off-checks are complete (STATE)

- To give engine run-up signal to #2
    - Pursuer(s): section lead
- To run up engines to 80%
    - Mutual Pursuer(s): section lead & #2

(Final checks complete, section lead & #2, STATE)

- To initiate take-off roll
    - Pursuer(s): section lead
    - To release brake
        - Pursuer(s): [unspecified]
        - To give head nod [for brake release]
            - Pursuer(s): section lead

(Brake release, section lead & #2, STATE)

- To advance [smoothly] power to full afterburner
    - Pursuer(s): section lead & #2

LG • To retard [slightly] power to full afterburner

- (small power margin (#2), LG (Lead Goal), CAUSE-OF)
    - Pursuer(s): section lead

C1 (Lift-off & Safely airborne, section lead & #2, STATE)

- To raise gear and flaps
- To deselect afterburner
- To accelerate to an en route airspeed of 360 KCAS
    - (KCAS, Knots Indicated (Calibrated-?) Airspeed, ACRONYM)
        - Pursuer(s): section lead

(C1, STATE)

- To take off in sequence as single ships and with 20 seconds spacing on the front aircraft
    - Pursuer(s): #2 & #3

(Uneventful, Take-off Sequence, STATE)
(Safely Airborne, CF-18 section, STATE)

- To climb to 1000 feet Above Ground Level (AGL) &
    - Pursuer(s): CF-18 section
- To manoeuvre to an OFFSET CARD tactical formation &
- To initiate an en route transit to the Tactical Rendezvous Point (TRP)

### 5.4.5 Transit to Tactical Rendezvous Point

Time (During en route transit to the TRP)

- To perform "G" awareness, MODE IV and airborne weapons checks
- To maintain an OFFSET CARD tactical formation
    - (1000 feet AGL, LOC)
        - Mutual Pursuer(s): CF-18 section
        - (CF-18 section, "PULLER," CALLSIGN)

Time (1621Z)

- (CF-18 section, TRP, ARRIVES)
- To extend 2 minutes past TRP along planned Sweep route &
- To enter a 2-minute left-hand racetrack pattern &
- To use tactical turns

WHILE (PULLER, RV with Tornado GR-1s, WAITING)

- To complete a FENCE CHECK

WHILE (PULLER, RV with Tornado GR-1s, WAITING)

Time [pre-briefed]
- To contact Tornadoes
  - Pursuer(s): Section lead
  - (Tornadoes, "DIRT," CALLSIGN)

Time (1626:42Z)
CFG: (Contact Tornadoes, Section lead of CF-18s, SATISFIED)
- To depart the TRP, OFFSET CARD tactical formation
  - (GroundSpeed (G/S), 420 kts, EQUAL)
  - (CF-18 section, Tornado GR-1 8-ship formation, Time (2', 30"), LEADS-BY)
  - To adjust pattern

**Page 5.7 (45)**

**5.4.6 Route Sweep**

- (Lateral Support, CF-18/GR-1 Mission, NOT ASSIGNED)
- (Procedures, InEffect, STATE)
  - (Procedures, AUTONOMOUS CONTROL, INCLUDE)
- (Bull's Eye (BE), Calls#1, SELECTED)
  - (Calls#1, Adversary Air Advisory & Other Mission Critical, PURPOSE)
  - (Calls#1, CF-18 section & Tornado GR-1 section, BETWEEN)
- (Graphic#1, Sweep Mission Routing, DISPLAYS)
  - (Graphic#1, Figure 5.2, EQUAL)

S2: (State)
- (Pre-briefed section AI Radar & Search and Sort plan discipline & OFFSET CARD Tactical Formation, CF-18s, MAINTAIN)
  - (SPEED (CF-18s), 420 kts)
  - (ALTITUDE (CF-18s), 1,000 feet AGL)
  - (CF-18s & GR-1, R3, EXIST-BETWEEN)

R3: (Relationship)
- (GR-1, 2 OR 3 Minutes, CF-18, AHEAD-OF-BY)

(S2, G3, PURPOSE-OF)

G3:
- To ensure section is not outflanked &
- To be able to engage adversary aircraft early
  - (If-Encountered, CONTINGENCY)

- To join the ACO LLTR
  - (LLTR, Low Level Transit Route, ACRONYM)
  - (**Wypt 2**, LOC)
    - (Wypt, Waypoint, ACRONYM)

- To encounter opposing formation of aircraft
  - (Adhering to ACO, APPEARANCE)
  - (Midway (Wypt 2 and 3) & Along (LLTR)), LOC)
    - (ACO, Airspace Coordination Order, ACRONYM)
    - (LLTR, Low Level Transit Route, ACRONYM)

**Page 5.8 (47)**

- * To SPIKE radar &
- * To illuminate RWRs
  - (RWR, Radar Warning Receiver, ACRONYM)
    - * Mutual Pursuer(s): ( CF-18 section and Tornado GR-1s) & Opposing Force)

- To EID opposing formation as 4 xF-16's
  - (APG-65 NCTR processing, EID, MEANS-OF)
  - (EID, Electronically Identified, ACRONYM)

ID1:

- * To VID F-16s pre-merge
  - (VID, Visually Identify, ACRONYM)
  - Pursuer(s): #2
    - To sort the friendly formation &
    - To manoeuvre for Purpose
      - * (Purpose, To enable #2 to VID F-16s pre-merge, EQUAL)
      - Pursuer(s): CF-18 section

- To communicate ID1 to GR-1 package
  - (Common Frequency, Communication, MEANS-OF)

- G2 To regain (OFFSET CARD tactical information & LLTR routing)
  - (LLTR, Low Level Transit Route, ACRONYM)
    - Pursuer(s): CF-18 section
  - (G2, "quickly," ACHIEVED-HOW)

- To push up to 480 kts G/S
  - Pursuer(s): CF-18 section
  - (Wypt#3, LOC)

(CLARA, STATE)
(G3, CLARA (STATE), CAUSE-OF)

- G3 To (NOT) encounter radar OR RWR OR Adversary air visual sightings
  - (RWR, Radar Warning Receiver, ACRONYM)
  - Pursuer(s): CF-18 section
  - (Wypt#3 and Wypt#4, DURIING-TRANSIT-BETWEEN)

- To implement EMCON procedures
    - Pursuer(s): CF-18 section
  - (Just Past Wypt#3, LOC)
  - (IFF OFFLINE, LOC)

- G4 To collapse to a FLOT CROSSING tactical formation
- To make better use of terrain masking
  - To descend
    - Pursuer(s): CF-18 section

- S3 To encounter adversary AI threats
  - (FEBA & FLOT, LOC)
    - (FEBA, Forward Line of Battle, ACRONYM)
    - (FLOT, Forward Line of Own Troops, ACRONYM)
  - (unlikely, PROB)

(S3, G4, REASON-FOR)

- To illuminate Section RWRs
  - (several times, FREQ)
  - (during and post FLOT crossing, TIME)
    - Pursuer(s): Adversary Ground-Based Systems

- G5 To transit to Wypt#5
- To observe (NOT) AI threat OR SAM launches
    - Pursuer(s): CF-18 section
  - (visual, MODE)

A1 (Activity 1):

(Aircraft manoeuvre & Visual lookout & use of terrain masking & employment of active RF jammers)

- (RF, Radio Frequency, ACRONYM)

(A1, G5, ENABLES)

- To observe multiple ground flashes & unmistakable smoke trail of surface-to-air missiles
    - Pursuer(s): #4
  - (Right 5 o'clock position, LOC)

WHEN:

(CF-18 element passes Wypt #5 & Exiting a coastal inlet & Entering an area of small islands)

- To (NOT) spike aircraft

(A2, A3, CAUSE-OF)

A2 (Activity #2)

- G6 To execute a missile break/maximum performance turn into the missiles' plane of turn
  - Pursuer(s): CF-18 section
  - To call for G6
    - Pursuer(s): #4
    - (on discreet frequency, HOW)

A3 (Activity #3)

- To deploy chaff and flares from the ALE-39 CMDS, via the panic button sill switch &
- To retard throttles &
- To manoeuvre through 60° of turn into missiles &
- To rapidly descend to DECK
  - Pursuer(s): #3 & #4

E1 (Effects #1)

- To strike flare decoy
  - Pursuer(s): [unspecified] SAM #1
- To impact sea
  - To acquire surface glint
    - Pursuer(s): [unspecified] SAM #2

A4 (Activity #4)

- To execute a hard 90° turn &
- To track parallel to the pre-planned route
  - To skirt to the seaward of a small island
    - (Outside the apparent SAM engagement zone, LOC)
      - Pursuer(s) #3 & #4

A5 (Activity #5)

- To push up to full military power &
- To extend along the pre-planned route
- Pursuer(s): Lead & #2

(A7, A6, CAUSE-OF)
A6 (Activity #6)

- To avoid missile site (M1)
    - To deviate from track
        - Pursuer(s): GR-1 (Tornado package)

A7 (Activity #7)

- To inform the Tornado package of I1

I1 (Information #1)

- - (A2-A4, SUMMARY-OF)

ME1 (Missile Engagement)
(CF-18 section Integrity, ME1, COMPROMISED-BY)

(CS, ME, CAUSED-BY)
CS (STATE (CURRENT):

- To (NOT) have VISUAL
- To be offset to the right 4 o'clock of lead element by 4 nm
- To be terrain masked amidst several small islands.
        - Pursuer(s): trailing element (#?)

- (LOS R/T, CF-18 elements(RE1), INHIBITED)
  (RE1, BETWEEN, EQUAL)

- (NEXT RV, 3-4 minutes along track, EQUAL)
    - (GR-1 Ingress into the IP and TGT area, LOC-APPROX)
        - (TGT, TarGeT, ACRONYM)
        - Pursuer(s): CF-18 & GR-1

- To Sweep the route
    - (Independently & rough LINE-A-BEARING formation to LOC, MEANS)
        - (RV, LOC)
        - Pursuer(s): CF-18 elements

(G8 & G9, A8, CAUSED-BY)

G9 • To reduce radar cross-section &

- To diverge from lead's flight path
    - To turn slightly into threat
        - (spiked, #2, STATE)
            - Pursuer(s): #2

G8 • To deviate from course
- To collapse combat spread (#2 inside the turn)
- To descend between two ridge lines
  - To manoeuvre

A8 (Activity #8)
Time (G7, SHORTLY-AFTER)
- To hear applicable radio alert tones
  - (pilot headsets, LOC)
    - Pursuer(s): Lead & #2
      - To acquire Lead & #2
        - Pursuer(s): Surveillance Engagement Radar (**SA-8**, ASSOCIATED-WITH)

G7 • To pass Wypt#6
- Pursuer(s): Lead

**Page 5.9 (47)**

(G10, STATE, CAUSED-BY)
G10:
- To execute a hard turn (4 'G') into the spike &
- To deploy multiple bundles of chaff
  - To use chaff/flare switch
    - (right throttle, chaff/flare switch, LOC)
  - (RWR Go critical, STATE)
    - Pursuer(s): #2

(G11, A9, CAUSED-BY)
G11
- To put the missiles on the beam
  - To turn hard
  - To deploy multiple bundles of chaff

A9 (Activity #9)
- To observe two missiles
  - (slightly high along OWN RWRs threat origin azimuth)
    - Pursuer(s): #2

STATE:
(ALQ-126B & ALQ-162 CW Jammers, Repeat Mode, STATE)

- To barrel into terrain on opposite ridge line
  - Pursuer(s): [unspecified] Missile #1
- To acquire chaff
  - Pursuer(s): [unspecified] Missile #2

- To regain formation integrity &
- To egress the SAM engagement zone
  - (general direction of the pre-planned route, LOC)
    - Pursuer(s): Lead & #2

- To transmit the second Sam engagement to the Tornado package

WHILE (To offset formation away from the IP as per mission pre-brief)

(G12, A10, CAUSED-BY)

G12

- To command APG-65 into AACQ mode &
- (AACQ, Auto-ACQusition, ACRONYM)
- To turn hard right 90° into the threat
- Pursuer(s): Lead & #2

A10 (Event #10)

Time (30 seconds (LATER))

- To spike Lead
- (4 o'clock position (Lead), LOC)
- Pursuer(s): [unspecified] AI radar

AS (To round extension of land)

- Pursuer(s): Lead element
- To manoeuvre for two independent weapons solutions
- Pursuer(s): Lead

- To achieve two sorted lock-ons

- To call "HOSTILE, hostile, Mig29" &
- To fire a SPARROW missile
- To turn hard away from the Mig to maximum radar gimbal limits (F-POLE) to the left and north of Lead
  - Pursuer(s): #2

STATE

(trailing element (CF-18), MISIDENTIFIED)

(trailing element (CF-18), TARGETED)

- To command a radar break-lock
- To call "FRIENDLY, friendly"
  - To visually identify the lead element on the beam
    - (rounds isthmus, #3, LOC)
  - Pursuer(s): #3

(G14, G13, CAUSE-OF)
G14
- To go ballistic & land in the sea
    - Pursuer(s): SPARROW

G13
- To break the lock-on
    - Pursuer(s): #2

- To rejoin
    - To call for an element-element cross turn

- To re-intercept its intended ground track
    - To navigate
        - To use CF-18 digital MMD & EGI as reference
          (EGI, Embedded Global Positioning/Inertial Navigation System, ACRONYM)

(MMD, Moving Map Display, ACRONYM)
- To extend in BATTLE tactical formation

Time (next two minutes)
TS1 (Threat Sector #1)
- To look directly into the target area
- (left quarter of CF-18s, LOC)
- To switch to 90° radar azimuth scan centred

- To radar observe multiple fast and low targets departing the field
    - (TS1, LOC)

- To draw adversary air away from PA11
    - To JINK 30° to the right
        - (JINK, ????, ACRONYM)

PA11 (Planned Activity #11)
- To ingress (IP to TGT)
    - Pursuer(s): GR-1

- To observe 4-aircraft formation
  (hot vector to CF-18s, LOC)

- To indicate CF-18s sampled/targeted
    - To [unspecified action] RWR &
    - To [unspecified action] audio indications

- To indicate GR-1s encountered threat activity

DURING
    - To ingress to target(s)
        - Pursuer(s): GR-1s
    - To have R/T
        - (much, AMOUNT)
        - (Common tactical frequency, LOC)

- To draw HEs away from the ingressing Tornadoes.
- To maintain radar contact on the hostile entities
    - (HEs, Hostile Entities, ACRONYM)
        - Pursuer(s); Lead element (CF-18s)
    - To FLOAT to near radar limits
        - (near radar gimbal limits, LOC)
            - Pursuer(s): CF-18s

- To call by the IP
        - Pursuer(s): GR-1 Lead

WHEN (bandits, 15 nm, CF-18s, LOC-FROM) & (bandits, hot intercept course, CF-18s, LOC-ON)

- To execute an element-element near-90° turn into the threat
        - Pursuer(s): CF-18 section

Time (25 seconds TTG)
    - (TTG, Time-To-Go
- To launch an AIM-7M
        - Pursuer(s): Lead

WHEN (Leads steering dot is in the NIRD circle
    - (NIRD, Normalised-In-Range Display, ACRONYM)

Time( ALMOST-SIMULTANEOUSLY)
- To launch a SPARROW
    - To acquire lead bandit pair wingman
        - Pursuer(s): #2

- To F-Pole
    - (North & East, DIRECTION)
        - Pursuer(s): Lead and #2

- To indicate hostile A-A missile launch
  - (A-A,, Air-to-Air, ACRONYM)
  - To record PDI
      - Pursuer(s): RWRs (Lead element (CF-18)
    - (PDI, Pulse Doppler Illumination, ACRONYM)

Time (10nn from bandits)

- To acquire, sort, target & launch SPARROWS on trailing bandits
    - Pursuer(s): #3 and #4

- To F-Pole
  - (North & West, DIRECTION)
    - Pursuer(s): #3 and #4

- To transmit "SPLASH four bandits" to GR-1s
  - (in the blind, HOW)

WHEN (all launched SPARROWS time out)

- To egress
  - (North & East, DIRECTION)
  - (target area, LOC-OF)
  - (Wypt#9, ENROUTE-TO)
    - Pursuer(s): CF-18 section

- To regain OFFSET CARD tactical formation
    - Pursuer(s): CF-18 section

- To call off target & declare one LOSER
    - Pursuer(s): GR-1s

**Page 5.10 (48)**

Time (1 minute late & two minutes ahead of DIRT)

- To arrive at Wypt#9
    - Pursuer(s): PULLER

A20 (Activity #20)
(Remainder of Sweep, uneventful, STATE)

- (along planned egress, LOC)

- To fly an OFFSET CARD tactical formation &
  - To adjust as required for terrain
- To maintain communication discipline &
- To adhere to the pre-brief threat lookout, search, sort, and targeting contract
    - Pursuer(s): CF-18 section

- To turn the IFF on
  - (IFF ON LINE, LOC)

- To collapse the formation
  - (Midway to Wypt#10, LOC)

WHEN • (prior to FLOT crossing)

- To detect no missile launches
  - (RWRs , LOC-ON) OR
  - (visually, MEANS)

- To illuminate briefly
  - (vicinity of the FLOT , LOC)
    - Pursuer(s): RWRs

- To (NOT) deviate from pre-planned egress route
    - Pursuer(s): CF-18 section

- To slow to 420 kts G/S
  - (Wypt#11, LOC)
    - Pursuer(s): CF-18 section

- To reduce speed to 360 kts G/S &
- To commence climb &
  - (Wypt#11, LOC)
  - (MTL, LOC-TO)
      - (MTL, 21,000 feet, EQUAL)
      - (MTL, Medium Transit Level, ACRONYM)
- To adjust the altimeters to 29.92 (inches of mercury)

(G20 & G21, C1, CAUSE-OF)

G20

- To collapse to two close-formation elements
    - Pursuer(s): CF-18 section

G21

- To maintain 2 nm radar-trail on lead element
    - Pursuer(s): trailing pair

C1 • (Inclement weather/IMC, STATE)

DURING (climb)

  - (IMC, Inclement Meteorological Conditions, ACRONYM)

- To join the TC &
- To contact the pre-briefed ground control agency
  - (Ground control agency, HARDTIRE (Call-sign), EQUAL)
  - (TC, Transit Corridor, ACRONYM)
    - Pursuer(s): CF-18 section

- To acknowledge clearance to proceed
  - (AAR area, LOC)
  - (AAR, SULLY, EQUAL)
  - (260, FL-AT)
    - (FL, Flight Level, ACRONYM)
    - Pursuer(s): Lead
  - To receive clearance to proceed
    - Sender(s): [unspecified]
      - To pass a MISREP
        - Pursuer(s): Lead

(Time 1715Z)
(1715Z, Conclusion of above activities, EQUAL)
- To declare mission successfully concluded

### 5.4.7 Air-to-Air Refuelling (DAY, VMC)

- To enter VMC

WHEN (During To climb & To (short) transit to AAR area SULLY)
(AAR area SULLY, Figure 5-3, DISPLAYED-IN)
  - (VMC, Visual Meteorological Conditions, ACRONYM)
    - Pursuer(s): CF-18 section

- To perform weapons safety check &
- To set pre-briefed A-A TACANs
  - (TACAN, Tactical Air Navigation, ACRONYM)
    - Pursuer(s): CF-18 section

- To authorize silent re-join and tanking procedures
    - Pursuer(s): [unspecified; likely RAF VC-10 tanker]
- To check-in briefly with RAF VC-10 tanker
  - (RAF VC-10 tanker, HOSER, CALLSIGN)
  - (TAD 23, HOW)
    - Pursuer(s): Lead (CF-18 section)

- [implication] To effect a nose-to-nose pass
  - To show 60nm to tanker with high closure
    - Pursuer(s): A-A TACAN

- To obtain a radar contact
  (46 nm, LOC-AT)
    - Pursuer(s): Lead (CF-18 section)

- To initiate a high angle off intercept course
    - Pursuer(s): Lead (CF-18 section)

WHILE (To collapse into FIGHTING WING tactical formation

        - Pursuer(s): (formation members – Lead) (CF-18 section)

LOC (12 nm)
(Visual contact on tanker, STATE)

- To reverse orbit to south
        - Pursuer(s): [unspecified; likely RAF VC-10 tanker]
    - To request tanker
        - Pursuer(s): Lead (CF-18 section)

A30 (Activity #30)
LOC (8 nm with 80 kts of closure (Vc))

    - (Vc, Velocity Closing (Overtake), ACRONYM)
- To initiate a climb &
  (1000 feet below the tanker (FL270), LOC-TO)
- To select EMCON &
- To slow to 290 KCAS &
- To re-join outboard of the VC-10's right wing &
- To assume the AAR OBSERVATION POSITION
    - (EMCON, Emission CONtrol, ACRONYM)
    - (KCAS, Knots Calibrated AirSpeed, ACRONYM)
        - Pursuer(s): CF-18 section

AAR Procedure #1
(AAR, Air-to-Air Refuelling, ACRONYM)

(A30, LOC-AT)

- To move outboard of the VC-10's left wing
        - Pursuer(s): #3 & #4 (CF-18 section)

- To drop astern the trailing hoses &
- To extend refuelling probes &

- To initiate contact with the re-fuelling drogue (basket)

...continued below

continued from above…

WHEN (cleared contact by AAR lights)

    - Pursuer(s): Lead & #3 (CF-18 section)

WHEN (Refuelled (Lead & #3), STATE)
- To disconnect &
    - Pursuer(s): Lead & #3 (CF-18 section)
- To move outboard of the left wing &
    - Pursuer(s): Lead (CF-18 section)
- To move outboard of the right wing &
    - Pursuer(s): #3 (CF-18 section)
- To retract fuelling probes
    - Pursuer(s): Lead & #3 (CF-18 section)

(AAR Procedure #1 Complete, STATE)

(AAR Procedure #2)
- To repeat AAR procedure
  - (#2 & #4, wingmen, EQUAL)
    - Pursuer(s): wingmen (CF-18 section)

(AAR Procedure #2 Complete, STATE)
- To rejoin Lead's element on the right wing
  - To manoeuvre
    - Pursuer(s): #3 & #4 (CF-18 section)

Time (1750Z)
- To depart the tanker

(Lead & #3, lowest fuel on board at 13,000 lb)

**Page 5.11 (49)**

### 5.4.8 High Value Airborne Asset Protection

(HVAA Protection Mission, Figure 5-4, DISPLAYED-IN)

(Clear of VC-10 tanker, CF-18 section, STATE)
(area SULLY, LOC-IN)

WHILE (enroute to assigned HVAA orbit(s))
- To descend to FL260

- To accelerate to .85 IMN
- To manoeuvre to a BATTLE tactical formation
    - (HVAA, High Value Airborne Asset, ACRONYM)
    - (IMN, Indicated Mach Number, ACRONYM)
        - Pursuer(s): CF-18s

DURING (transit)

- To re-program mission data into the EGL &
- To change AI radar channelization &
- To adjust radar search patterns &
- To adjust DEWS settings &
- To conduct FENCE CHECKS (as per mission pre-brief)
    - (DEWS, Defensive Electronic Warfare Suite, ACRONYM)
        - Pursuer(s): CF-18s

- To establish radar contact on the HVAA &
    - (HVAA, NATO E-3 AWACS, TYPE-OF-AIRCRAFT)
    - (HVAA, MAGIC, CALLSIGN)
- To initiate radio contact on TAD 17
        - Pursuer(s): Lead (CF-18 section)

- To request PULLER to change IFF codes
  (PULLER, CF-18 section, EQUAL)
    - To request CF-18 section to authenticate
        - Pursuer(s): MAGIC

[Implication from above request]

- To change IFF codes
    - To authenticate
        - Pursuer(s): PULLER

**Page 5.12 (50)**

- To hand off PULLER to its tactical IND
    - (IND, Intercept Director, ACRONYM)
    - (IND, SMURF, LOC)
    - (SMURF, AWACS, CALLSIGN)
    - (TAD14, ??, ??)

Time (On check-in)

- To give ON-STATE times and weapons loads.
        - Pursuer(s): Lead (CF-18 section)

- To direct PULLER to change CALLSIGN to RED and BLUE &
- To climb ANGELS 31 & 33, respectively (??) &
- To proceed to CAP datums

- (CAP, Combat Air Patrol, ACRONYM) -?
- (CAPS DATUM, "positioned so that it offers the element/section the best opportunity of defending their point/AOR with hot leg facing suspected threat direction," EQUAL)
- (ANGELS, Altitude (thousands of feet), ACRONYM)
    - Pursuer(s): SMURF

Time (At this point)
- To request #3 & #4 to leave the section
    - Pursuer(s): Lead (CF-18 section)

[Implication]
- To leave the section
    - Pursuer(s): #3 & #4 (CF-18 section)

Time (Now)
- (CF-18 section, two distinct (2-ship) elements, EQUAL)
    - (two distinct (2-ship) elements, RED AND BLUE, EQUAL)

(LINK 16, G31, DISPLAYING)

G31
- To proceed to OWN backstop/goalkeeper CAP datum
    - (ANGELS 35, ALTITUDE)
        - (ANGELS, Altitude (thousands of feet), ACRONYM)
    - Pursuer(s): RNAFF-16s
        - (RNAFF-16s, GOLD, CALLSIGN)

- To advise the LINK 16 has been intermittent &

IF
- To go down (LINK 16)
    - Pursuer(s): SMURF

THEN
- To use pre-briefed BE for bogey BROADCAST CONTROL calls

UNTIL
- To elect to G32
    - Pursuer(s): CF-18 section

G32
- To commit out their CAPS
    - Pursuer(s): CF-18 section

AT-TIME:
- To provide LOOSE CONTROL
    - Pursuer(s): ??

- To request RED to G33
    - Pursuer(s): SMURF

G33
- To establish CAP datum hot legs timing for RED & BLUE &
  - (threat sector, LOC-INTO)
- To ensure that GOLD flies opposing CAP timing.

WS1 (Weather State #1)
(WS1, an undercast cloud layer, EQUAL)
(Area Weather, WS1, DISPLAYING)
- (variable from ANGELS 15 TO 19, LOC)

EXPECTATION (CONTRAILS, (ANGELS 42, ALTITUDE))
- (ANGELS, Altitude (thousands of feet), ACRONYM)

(High cirrus clouds, Above, LOC)

Time (End of above,1800Z, EQUAL)

**Page 5.13 (51)**

- To confirm
  hot and cold legs timing &
  A-A TACAN channelization
  radar search, sort, targeting & commit criteria
  - (out of the CAP datums, LOC - ??)
  - (as per the HVAA mission pre-brief)
    - Pursuer(s): CF-18 section

STATE: (Six fighters, an MFFO, FUNCTIONING-AS)
ALTHOUGH (CAPs, geographically distinct)

(LINK 16, G32, DISPLAYING)

G32
- (MAGIC established in a 20 nm figure-eight pattern, STATE)
  - (sanctuary, ALTS1, LOC)
    - (ALTS, ANGELS 28-30, ALTITUDE-BETWEEN)
  - (assigned datum, LOC-AT)
  - (assigned datum, 70 nm to south-east of RED & BLUE CAPs, EQUAL)
    - (ANGELS, Altitude (thousands of feet), ACRONYM)

Time (1807Z)
- To initiate CAP datum hot-leg timings for RED and BLUE
  - Pursuer(s): RED

Time (NOW)
- To turn cold
  - Pursuer(s): GOLD

(Absence of target activity, STATE)
- To transmit CLARA
    - Pursuer(s): SMURF

Time (1810Z)
(as forward CAPS are turning cold, STATE)

(LINK 16, G32, DISPLAYING)

G33
- To climb and accelerate on a hot vector
    - (some 170 nm from the E-3 orbit point, LOC)
        - Pursuer(s): multiple targets

Time (NOW & for next several minutes)
- To maintain CAP integrity &
- To maintain search discipline
    - Pursuer(s): fighters [CF-18 section implied - ??]

AS (LINK 16, trajectory of unknowns, MONITORED [DISPLAYING implied])

Time (1812Z)
- To advise DOLLY BENT
- To broadcast bogey updates
    - (BE, LOC-FROM)
        - Pursuer(s): SMURF

Time (1814Z)
- To broadcast two distinct target groups
  (#1, trailing by 10 nm)
  (both maintaining hot vectors to E-3)
    - Pursuer(s): SMURF

Time (1815Z)
- To pass east to the BE data point
    - Pursuer(s): bogeys

      Time (Just as)
      - To turn hot
          - Pursuer(s): RED & BLUE

AS per Mission Brief
- To RETROGRADE
    - (RETROGRADE, Directive/descriptive indicating that HVAA is egressing from assigned orbit point, away from known threat, EQUAL)
        - Pursuer(s): MAGIC

- To accelerate in afterburner &
- To commit on the bogeys

WHILE

- To maintain CAP discipline
    - Pursuer(s): RED & GOLD

- To declare two elements of BANDITS
    - (ANGELS 41, Lead element (BANDITS), ALTITUDE)
    - (Mach 1.2, Lead element (BANDITS), SPEED)
    - (laterally split 2 nm, Lead element (BANDITS), POSITION)
        - (ANGELS, Altitude (thousands of feet), ACRONYM)
            - Pursuer(s): SMURF

- To descend &
- To accelerate
    - (RETROGRADE vector (OWN), LOC)
        - Pursuer(s): MAGIC

- To call going ORANGES SOUR
    - (ANGELS 19, ALTITUDE)
        - (ANGELS, Altitude (thousands of feet), ACRONYM)
    - Pursuer(s): SMURF

- To transmit BRAA report
  (BRAA, Bearing Range, Altitude and Target Aspect, ACRONYM)
        - To obtain radar contact on lead bandit element
            - (35 nm, LOC-AT)
    - Pursuer(s): BLUE
- To radar sort the information
  (Continuous, HOW)
    - Pursuer(s): BLUE lead

WHILE

- To establish initial radar contact on the trailing pair
    - (ANGELS 32, ALTITUDE)
        - (ANGELS, Altitude (thousands of feet), ACRONYM)
    - Pursuer(s): wingman (BLUE) [BLUE 2 - ??]

(25 nm to lead bandit, LOC

- To advise flight lead that trailing pair (bandits) have POST-HOLED
    - Pursuer(s): BLUE 2

- To direct wingman W(B)G1 (Wingman (BLUE) Goal #1)
    - Pursuer(s): BLUE lead

W(B)G1

- To drop acquisition on the trailing pair
- To sort and target side-by-side on the lead bandits

- Pursuer(s): Wingman (BLUE)

(RWRs (CF-18s), ACTIVE, STATE)
(RWRs (CF-18s), (Not) indicate PDI, STATE)
  - (RWR, Radar Warning Receiver, ACRONYM)
  - (PDI, Pulse Doppler Illumination, ACRONYM)

(15 nm, LOC)
- To initiate a DRAG/PUMP &
- To initiate a rapid descent
  - (DRAG, Descriptive call indicating targets are diverging from previous flight path; generally associated with a TA greater than 110°, EQUAL)
  - (PUMP, A 180° reversal turn. Generally associated with a manoeuvre by to the original flight path, EQUAL)
    - Pursuer(s): Lead bandits

(Sorted, BLUE lead and BLUE 2, STATE)
- To launch 2 x AIM-120 missiles
- To transmit "FOX-3, FOX-3"

- To give BLUE a snap vector to the trailing bandit pair
  - ((trailing bandit pair, 15 nm, LOC-AT) &
  - (ANGELS 17, ALTITUDE))
  - (trailing bandit pair, Mach .95, SPEED)
      - (ANGELS, Altitude (thousands of feet), ACRONYM)
    - Pursuer(s): SMURF

- To establish initial radar contact &
- To give a quick BRAA report to flight lead
- To EID the bandits as Mig-29s
  - (EID, Electronically IDentified, ACRONYM)
    - Pursuer(s): BLUE 2

- To sort the bandits lead trail &
- To fire AIM-7Ms
- To F-POLE away from one another
    - Pursuer(s): BLUE lead & BLUE 2

- To deploy chaff & flares
  - To use CMDS sill switch
    - Pursuer(s): BLUE 2
      - To indicate a bandit missile launch
        - Pursuer(s): RWRs (BLUE 2)
- To call "North is GREEN"
    - Pursuer(s): SMURF

Time (TTG, zero, EQUAL)
    - (TTG, Time-To-Go, ACRONYM)

- To egress to the north &
- To climb to ALT5
        - (ALT5, ANGELS 33, ALTITUDE)
    - To manoeuvre (S-Goal)
    - (ANGELS, Altitude (thousands of feet), ACRONYM)
        - Pursuer(s): BLUE lead and #2
- To give a snap vector to BLUE 2 to lead (BLUE 2)
    - To confirm two bandits splashed
        - Pursuer(s): SMURF

- To reverse course for the CAP datum &
- To acquire with radar &
- To re-join

(DOUBLE ATTACK, BLUE 2, TACTICAL-FORMATION-TYPE)
DURING (transit back)

(Time (1821Z), Above Activities Complete, STATE)

- To continue to monitor the air situation

WHILE (To manoeuvre back to OWN original orbit datum)
(OWN original orbit datum, assigned altitude block, LOC-IN)
- Pursuer(s): MAGIC

Time (ever few minutes)
- To pass CLARA advisories to fighters
    - Pursuer(s): SMURF

WHILE (To execute counter-rotating CAPs)
- Pursuer(s): fighters [CF-18s implied]

Time (1834Z)
- To call gadget SICK
    - (gadget, Radar, EQUAL)
    - (SICK, Descriptive call indicating described equipment is degraded (as in, 'gadget sick'), EQUAL)

**Page 5.14 (52)**

Time (1838Z)
- To advise radar contact on a group of bandits
    - (40 nm west-north-west of the BE, LOC-AT)
    - (on a hot vector to the E-3, LOC-DIRECTION)
        - Pursuer(s): SMURF

- To turn south-east &

(ABOUT (To turn hot))
        - Pursuer(s): RED
    - To direct GOLD to execute G40 &

G40
    - To leave his (GOLD) CAP datum &
    - To join RED in battle [BATTLE - ?] formation &

- To direct BLUE to execute G41 &
    - Pursuer(s): RED

G41
        - To assume goalkeeper CAP datum
            - Pursuer(s): BLUE

- To acknowledge and comply
    - Pursuer(s): RED & BLUE
- To retrograde
    - Pursuer(s): MAGIC

Time (1840Z)
- To call TIED
    - (TIED, Descriptive call indicating aircraft has visual sight or radar contact with referenced aircraft and will maintain relative position, EQUAL)
        - Pursuer(s): RED

- To turn into the threat sector &
- To commit on SMURF's bandit calls
    - Pursuer(s): RED & GOLD
    - To indicate BE 230°/20 nm & ALT6 & flight size four
        - (ALT6, ANGELS unknown, ALTITUDE)
        - (ANGELS, Altitude (thousands of feet), ACRONYM)
            - Pursuer(s): SMURF

- To accelerate to supersonic speed &
- To bracket the possible bandit flight paths
    - To quickly adjust radar azimuth &
    - To quickly adjust elevation scans
        - Pursuer(s): RED & GOLD

- To sample a radar contact at 40 nm &
- To show 10° TA & ALT7 & Mach 1.1
    - (ALT7, ANGELS 28, ALTITUDE)
        - (TA, Target Aspect, ACRONYM)
        - (ANGELS, Altitude (thousands of feet), ACRONYM)
    - Pursuer(s): RED lead

- To advise flight size of four
  - (rough line-abreast, FORMATION)
    - To confirm contact
      - Pursuer(s): SMURF

LOC (30 nm)

- To advise two radar contacts
  (ALT8, #1)
  (ALT8, ANGELS 35, ALTITUDE) &
  (Climbing, ALTITUDE-DIRECTION)
  (ALT9, #2)
  (ALT9, ANGELS 24, ALTITUDE)
    - Pursuer(s): RED

- To direct GOLD to target the contact at ALT11
  (ALT11, ANGELS 35, ALTITUDE)
    - Pursuer(s): RED

LOC (25 nm)

- To notice a momentary contrail, beaming to the west
    - Pursuer(s): GOLD lead

LOC (22 nm)

- To realise UG1
    - Pursuer(s): GOLD lead & GOLD 2

UG1 (Unintentional Goal #1) - ??

- To sort too high, supersonic targets, both dragging in opposite directions and away from bandit(s) targeted by RED
    - Pursuer(s): GOLD lead & GOLD 2

- To target western bandit &
- To clear GOLD 2 off to G42
    - Pursuer(s): GOLD lead

G42

- To target and splash the target beaming to the east
    - Pursuer(s): GOLD 2

- To engage the bandit(s)
  - To descend to ALT12
    - (ALT12, ANGELS 24, ALTITUDE)
      - Pursuer(s): RED

(R/T intensifies, STATE- AS)

- To attempt to build and relay SA &
- To transmit engagement tactics & bandit reaction
    - (SA, Situational Awareness, ACRONYM)
        - Pursuer(s): RED & GOLD

- To indicate G43
    - To confirm geometry
        - Pursuer(s): SMURF

G43

- To successfully target bandit formation
    - (two separate, two-versus-two, A-A engagements, HOW-IN)
        - Pursuer(s): RED & GOLD

- To indicate G44
        - Pursuer(s): RWRs (CF-18 section [unspecified])

G44

- To sample friendly fighters and sort
        - Pursuer(s): bandits - ??

LOC (18 nm)

- To sort two bandits

    (RAID mode & ALT13, two bandits, ATTRIBUTES)

        (ALT13, ANGELS 24 & 21, ALTITUDE)
        - Pursuer(s): RED lead

LOC (12 nm)

- To confirm a lead-trail formation with wingman offset to west
        - Pursuer(s): RED lead

- To call sorted &
- To fire AIM-120 missile at bandit lead &
- To pump
    - (PUMP, A 180° reversal turn. Generally associated with a manoeuvre by to the original flight path, EQUAL) – grammar error??
        - Pursuer(s): RED lead

- To be unable
    - To try G45
        - Pursuer(s): RED 2

G45

- To command a STT
  - (STT, Single Target Track, ACRONYM)
    - Pursuer(s): RED 2

- To press to the merge
  - To call CLEAN
    - Pursuer(s): RED 2

- To direct RED lead to PITCHBACK
  - To observe G46
    - (PITCHBACK LEFT/RIGHT, A call for fighter/flight to execute a hard to maximum performance nose-high 180° heading turn reversal. Most commonly used to re-engage after extending past the target aircraft/merged plot. It is also used when an excess of energy/airspeed exists. In all cases the fighter/flight must have situational awareness on the target, EQUAL)
      - Pursuer(s): RED 2

G46

- To score a kill on bandit leader
    - Pursuer(s): missile [unspecified (RED lead)

- To make a high angle-off unobserved entry to the merge &
- To lock on in VACQ mode &
- To manoeuvre out of plane
    - Pursuer(s): RED 2

- To acquire RED 2 &
- To jam RED 2
  (before G47, TIME)
    - Pursuer(s): surviving bandit

G47

- To launch an boresight AIM-9M
    - Pursuer(s): RED 2

- To enter into a neutral VERTICAL ROLLING SCISSORS fight
    - Pursuer(s): surviving bandit & RED 2

- To call engaged, neutral
    - Pursuer(s): RED 2

- To regain visual &
- To regain a TALLY
  (TALLY, Descriptive call indicating sighting of a bogey/bandit, EQUAL)
    - Pursuer(s): RED lead

- To achieve a radar lock-on
  - To use HMS/HMCS
    - Pursuer(s): RED lead

- To call engaged &
- To direct RED 2 to G48 &
- To score a clean AIM-9M kill on the trailing bandit

G48

- To COMEOFF RIGHT
  - (COMEOFF LEFT/RIGHT, Directive command to reposition after an aerial engagement, in order that mutual support be maintained/regained. Normally used by supporting fighter during two-ship role change, EQUAL)

- To direct RED 2 to G49
    - Pursuer(s): RED lead

G49

- To egress south
    - Pursuer(s): RED 2

- To quickly regain visual &
- To quickly regain MUTUAL SUPPORT
  - (MUTUAL SUPPORT, Mutual support means that all members of the formation will provide the other aircraft with offensive and defensive mutual support. Offensive mutual support means that you have used your aircraft's handling characteristics and fire control system, in concert with those of your formation members to effect a bandit kill. Defensive mutual support means that, as formation, you have manoeuvred together, but out of plane, to negate/survive a bandit attack, EQUAL)
    - Pursuer(s): RED lead & RED 2

Time (approximately one minute later)

- To splash assigned targets
  (12 nm, F-16s, LOC-APART)
    - Pursuer(s): F-16s

- To direct ROUND-UP
  (CAP datum, LOC)
    - Pursuer(s): GOLD lead

- To declare battle damage
    - Pursuer(s): GOLD 2

- To provide GOLD lead radar vectors for G50 &
- To hand off GOLD lead, GOLD 2 to a new intercept director on TAD 11 for emergency diversion
  - (TAD, Tactical Air Designator (Radio Frequency), ACRONYM)
    - Pursuer(s): SMURF

G50

- To re-join GROUP
  - (GOLD lead, GOLD 2, GROUP)

- To elect G51
    - Pursuer(s): RED

G51

- To join BLUE
  - (goalkeeper CAP datum, LOC)
    - Pursuer(s): RED

- To enter that CAP in a counter-rotating set-up
  - (1851Z, TIME)
    - Pursuer(s): RED

Time (1855Z)

- To declare 10 minutes PLAYTIME
  - (PLAYTIME, Descriptive call indicating amount of available on-station time; expressed in minutes, EQUAL)

- To acknowledge &
- To clear four CF-18s to G52
    - Pursuer(s): SMURF

G52

- To rejoin At ALT15
  - (ALT15, ANGELS 26, ALTITUDE)
- To depart the CAP datum
  - (AAR area SULLY, FOR-LOC)
  - (PULLER, CALLSIGN)

- To rejoin in element &
  - (2 nm radar trail, LOC)
    (1910Z, sunset, TIME)
- To declare ammo and fuel states &
- To renumber &
- To commence en route transit
  (SULLY, LOC)
    - Pursuer(s): CF-18s

**Page 5.15 (53)**

### 5.4.9 Air-to-Air Refuelling (Night, IMC)

(IMC, Instrument Meteorological Conditions, ACRONYM)

- To enter intermittent IMC

DURING (transit to AAR area SULLY)

        - (transit to AAR area SULLY, Figure 5-5, DISPLAYED)
        - (IMC, Instrument Meteorological Conditions, ACRONYM)
            - Pursuer(s): CF-18 section

- To perform a weapons safety check &
- To set pre-briefed A-A TACANs
    - Pursuer(s): CF-18 section

- To check-in briefly with (same) RAF VC-10 tanker
    - (RAF VC-10 tanker, HOSER, CALLSIGN)
    - (TAD 23, COMMUNICATE-ON)

- To authorize G53
    - Pursuer(s): HOSER

G53

- To silent re-join &
- To follow tanking procedures - ??
    - Pursuer(s): CF-18 section

- To display X1
    - Pursuer(s): A-A TACAN (CF-18 section)

X1
(85 nm to tanker, DISTANCE) &
(with low pressure - ??)

(X1, G54, IMPLICATION-OF)
G54

- To make a stern pass [of HOSER-??]
    - Pursuer(s): CF-18 section

- To request HOSER G55
    - Pursuer(s): CF-18 lead

G55

- To turn to the north-east
    - Pursuer(s): HOSER

- To obtain radar contact

WHILE (G55)

    - Pursuer(s): CF-18 lead

WHEN
(20°, Tanker TA, STATE)

- to facilitate the radar re-join
    - to roll out its [tanker's] turn
        - Pursuer(s): PULLER

- To call oranges SWEET &
- To advise that weather deteriorated in SULLY &
- To advise that AAR will have to be done in X2
    - Pursuer(s): HOSER

X2
(in and amongst cloud layers &
in low visibility &
in night conditions)

(15 nm, LOC)

- to request tanker G55
    - Pursuer(s): PULLER

G55

- To reverse course to the south-west
    - Pursuer(s): tanker

- To collapse from radar trail to a lose FINGER formation &
- To accommodate approaching darkness and inclement weather conditions
    - To adjust position and formation lights
        - Pursuer(s): CF-18s

**Page 5.16 (54)**

DURING (tanker turn & roll-out)
(SW heading, DIRECTION)

- To arrive at LOC
- (6000 feet astern tanker & 80 kts overtake, LOC)
    - To monitor TA, range and Vc &
    - To adjust angle of bank, power & climb attitude

- To visually acquire the VC-10
  - To maintain radar lock-on &
  - To monitor & control position of TD box &
    - (TD, BOX, LOC-IN)
  - To slow to 290 KCAS
    - (KCAS, Knots Calibrated AirSpeed, ACRONYM)
  - To close on tanker
    - Pursuer(s): CF-18 lead

- To position section &
  - (outboard of tanker's right wing, LOC)

(Once Settled, STATE)

- To clear #3 & #4
  - (outboard of tanker's left wing, LOC)

- To manoeuvre to ECHELON formation &
  - (outboard of tanker's wings, LOC)
- To complete the remainder of pre-RV checks
  - Pursuer(s): two elements [implied #3 & #4]

(elements firmly established outboard, STATE)

- To drop refuelling hoses
  - Pursuer(s): tanker

WHEN (cleared contact by the AAR lights)

- To initiate contact with the refuelling drogue (basket)
- To extend refuelling probes
- To drop astern the trailing hoses
  - Pursuer(s): CF-18 lead & #3

Time (at this point, STATE)
(darkness arrived at FL280 & cloud cover has thickened to near total IMC, STATE)

A10 (Activity #10)
Time (refuelled (lead & #3))

- To disconnect &
- To move outboard of wingmen (CF-18) &
  - (right wing of HOSER, wingman1 [unspecified], POSITION)
  - (left wing of HOSER, wingman2 [unspecified], POSITION)
- To retract fuelling probes
  - Pursuer(s): CF-18 lead & #3

Time (at this point, STATE)
(at this point, A10 complete, EQUAL)

- To move astern the hoses for contact

[implied A11, Complementary to A10 for #2 & #4]

WHILE (#2 & #4 refuelling, STATE)
G56
- To remain within AAR area SULLY
  - To enter a navigation turn to the north-east
    - (navigation turn to the north-east, roll-out(tanker), EQUAL)
      - Pursuer(s): tanker

(becomes quite turbulent, air, STATE)
DURING G56
- To disconnect (inadvertently) [implied: from refuelling drogue]

(G56 complete, STATE)
- To re-connect [implied: to refuelling drogue]
  - Pursuer(s): #4

G57
- To (fail to) make (satisfactory) probe contact with drogue (tanker)
  - Pursuer(s): #2

(S20, G57, CAUSE-OF)

S20 (STATE #20)
(severe oscillation, refuelling hose, STATE) &
(severe oscillation, aircraft buffet, STATE)

(G56 complete, STATE)
(4th attempt to G57, #4, STATE)

(Closure rate (#2), A50, CAUSE-OF)

A50 (Activity #50)
(Displacement of drogue & violent tip-off, STATE)

- To contact right-side of nose area(#2)
  - Pursuer(s): drogue basket

W2 (Warning #2)
- To illuminate &
  - Pursuer(s): master caution light (#2)
- To alert ("engine right, engine right") &
  - Pursuer(s): [unspecified voice alert (#2)]
- To alert ("engine right, engine right") &
  - Pursuer(s): [unspecified caution display (#2)]

ACCOMPANYING (W2)

- To lose thrust &
- To drop below and astern the tanker
    - Pursuer(s): CF-18(#2) - ?? [How do we represent a "failure" of the aircraft, not an action of the aircraft-under-pilot-control]

- To make (judicious) use of afterburner to (safely) clear the tanker
    - Pursuer(s): #2

- To notify lead of the emergency &
- To advise SELF has full control of aircraft &
- To advise that SELF able to recover independently
  - To make controlled descent to level flight at FL260
    - Pursuer(s): #2

- To provide #2 PIGEONS &
  - (Nearest suitable diversion base, LOC-TO)
  - (PIGEONS, Descriptive R/T request for bearing and range to a referenced point; e.g., 'pigeons home plate', EQUAL)
- To clear #2 for single-ship recovery
    - Pursuer(s): PULLER lead

- To advise PULLER #2 G58
    - Pursuer(s): HOSER

G58

- To contact MAGIC
  (TAD 19, HOW)
    - Pursuer(s): PULLER #2

- G58
- To clear PULLER #2 to contact NEATISHEAD approach control for emergency landing
  (NEATISHEAD, Night AAR Mission emergency diversion airfield, EQUAL)
    - Pursuer(s): MAGIC

- To execute G59 &
  - (safely, HOW)
  - (in accordance with emergency procedures for a right engine out, HOW)
  - (in accordance with emergency procedures for loss of hydraulic 2A pressure (typical of angle of attack vane ingestion into right engine, HOW)

G59

- To land
  - To approach
    - To descend & &
      - Pursuer(s): PULLER #2

- To (successfully) complete tanking &
- To move outboard of #3 on tanker's left wing &
- To retract fuelling probe
    - Pursuer(s): #4

- To rejoin lead
  - (right wing, LOC-ON)
    - To manoeuvre

Time (at this point)

- To clear G60
    - Pursuer(s): HOSER [implied]

G60

- To depart tanker
    - Pursuer(s): CF-18 3-ship

(Lowest fuel on board, Lead, STATE)

- (13,400 Lb. , Lead, FUEL-On-BOARD)

Time (1950Z)

**Page 5.17 (55)**

## 5.4.10 Fighter Area of Operational Responsibility

(clear of VC-10 tanker, PULLER, STATE) &
(en route to its FAOR, PULLER, STATE)

  - ((FAOR, Figure 5-6, DISPLAYED-IN)
- To descend to FL220 &
- To accelerate to .85 IMN &
- To manoeuvre to a radar trail formation (one plus two) &
- To join the MRR
  - (MRR, Minimum Risk Routing, ACRONYM)
    - Pursuer(s): PULLER

- To brief new AI radar channelisation & A-A TACANs &
- To assign a search, sort, target and commit plan
  - (search, sort, target and commit plan, new 3-ship formation configuration, BASED-ON)

        - Pursuer(s): PULLER

- To confirm DEWS settings &
- To re-program essential mission data into the EGI &
- To perform FENCE CHECKS
    (EGI, Embedded Global Positioning/Inertial Navigation System, ACRONYM)
    (MMD, Moving Map Display, ACRONYM)
    - (FENCE CHECKS, FAOR mission pre-brief, ACCORDING-TO)
        - Pursuer(s): Flight members (CF-18 (3-ship) section)

A60 (Activity #60)
- To re-name the formation as STAG
    - (re-naming procedure, ATO, ACCORDING-TO) - ??
- To not re-number [implied: the formation]
        - Pursuer(s): Lead (CF-18 (3-ship) section)

(A60, Lead will fly as with a phantom #2, IMPLIES)

Time (1955Z)
- To initiate radio contact with FAOR mission ground-based radar
    - (FAOR mission ground-based radar, BULMER, CALLSIGN)
    - (TAD 12, Lead (CF-18 (3-ship) section), COMMEANS)

    - To request G61 &
    - To issue FAOR altimeter setting.
        - Pursuer(s): BULMER

G61
- To authenticate &
- To change IFF codes
        - Pursuer(s): STAG

**Page 5.18 (56)**

- To confirm radio contact on STAG &
- To authorise descent to assigned mission sanctuary altitudes &
- To authorise direct routing to FAOR datum
        - Pursuer(s): BULMER

WHEN (enroute [to where?], STATE)
- To transmit an adjacent FAR
        - Pursuer(s): STAG

- To target STAG
    - (4 x F-3, DART, CALLSIGN)
        - Pursuer(s): 4 x F-3

To interrogate IFF (each other's) as friendly
        - Pursuer(s): fighters [??]

Time (2000Z)
- To call ON-STATE with 70 minutes playtime &
- To indicate that any commit will be done as a 3-ship
    - Pursuer(s): STAG

- To acknowledge with
    - (CLARA, STATE)
        - Pursuer(s): BULMER

- To establish a 20 nm counter-rotating CAP at ALT17 & ALT18 at FAOR datum
    - (370 KCAS, AIRSPEED)
    - (ALT17, ANGELS 11, ALTITUDE)
        - Pursuer(s): Lead
    - (ALT18, ANGELS 12, ALTITUDE))
        - Pursuer(s): Trailing pair

    (ANGELS, Altitude (thousands of feet), ACRONYM)
        - (FAOR, Fighter Area of Operational Responsibility, ACRONYM)
        - (KCAS, Knots Calibrated AirSpeed, ACRONYM)

(G63, G62, PURPOSE-OF)
G62
- To ensure continuous fighter radar coverage into the threat sector to the north
    - Pursuer(s): ??

G63
- To co-ordinate hot and cold leg timings
    - Pursuer(s): ??

- To advise S30 &
- To inform G64

S30 (STATE #30)
(LINK 16, Available, STATE)

G64
- To confirm intermittent LINK 16 operation
    - Pursuer(s): MAGIC

- To designate a common BE for the adjacent FAORs &
    - Pursuer(s): BULMER

(S32, G65, REASON-FOR)
G65

- To indicate that SELF able to provide broadcast control only WHEN-IN-STATE S31
  - (FAOR, Fighter Area of Operational Responsibility, ACRONYM)
    - Pursuer(s): BULMER

S31 (STATE #31)

- (DOLLY going bent)

S32 (STATE #32)

- (Poor radar coverage, STATE)
  - (area terrain, LOC)

- To brief S33
    - Pursuer(s): BULMER

S33 (STATE #33)

- (area weather, undercast, STATE) &
- (cloud cover, five to eight tenths, STATE) &
  - ( 3,000 feet MSL, 8,000 feet MSL, FROM-TO)
    - (MSL, Mean Sea Level, ACRONYM)
- (1,400 feet, FAOR mean terrain height (variable), STATE)
  - (FAOR, Fighter Area of Operational Responsibility, ACRONYM)

Time (2017Z)

- To show four friendly aircraft G66

G66

- To transit toward STAG's FAOR
  - (diagonally, DIRECTION)
  - (lead trail, FORMATION-IN)
  - (an ACO LLTR, ALONG (DIRECTION - ?))
  - (450 kts, G/S)
  - (FAOR, Fighter Area of Operational Responsibility, ACRONYM)
  - (ACO, Airspace Coordination Order, ACRONYM)
  - (LLTR, Low Level Transit Route, ACRONYM)
  - (G/S, Ground speed (in kts), ACRONYM)
    - Pursuer(s): LINK

- To deviate from the LTTR &
  (suddenly, HOW)
- To increase G/S
  - (30 nm from STAG's FAOR, LOC-AT)
    - (FAOR, Fighter Area of Operational Responsibility, ACRONYM)
    - (LLTR, Low Level Transit Route, ACRONYM)
    - (G/S, Ground speed (in kts), ACRONYM)
  - Pursuer(s): 4-ship

G67
- To show friendly
  (still, HOW)
    - Pursuer(s): LINK 16

- To advise BULMER G67
    - Pursuer(s): LINK 16 - ??

BUT
- To (be unable to) confirm status OR
- To (be unable to) confirm radar contact
    - Pursuer(s): BULMER

- To show target status changed as unknown - ??
  - (25 nm miles to targets, LOC)
    - Pursuer(s): LINK 16 - ??

- To direct #3 & #4 to G68

G68
- To rejoin in 2 nm trail
  - (at that time, TIME)
  - (on opposite side of the race track pattern, LOC)
  - (hot, CONDITION) - ??

- To turn into the threat &
- To accelerate to 420 KCAS

AS
- To commit out of the CAP pattern
    - Pursuer(s): STAG Lead

- To direct a lead-trail sort contract with wingmen &
- To target the trailing pair
  - To advise an initial intercept geometry
    - Pursuer(s): STAG Lead

- To establish radar contact on the bogeys
  - (20 nm, LOC-AT)
  - (on the deck, LOC)
  - (.95 IMN, SPEED)
    - (IMN, Indicated Mach Number, ACRONYM)
  - (off LLTR, LOC)
    - (clearly, HOW)
    - (LLTR, Low Level Transit Route, ACRONYM)
    - Pursuer(s): STAG [Lead(?)]

- To (still) show target status unknown
    - Pursuer(s): LINK 16

- To establish a (slightly hot) 150° HCA right to left intercept course &
  - To manoeuvre 3-ship (S-Goal)
    - (HCA, Heading Crossing Angle, ACRONYM)
  - To descend to 2,000 feet AGL
      - (still in cloud, STATE)
    - Pursuer(s): Lead

- To interrogate the targets as hostile &
- To (immediately) accelerate to 500 KCAS
  - (15 nm from lead bogey pair, LOC-AT)
    - Pursuer(s): STAG Lead

- To sort the targets in TWS &
- To note Lead Bandit G69
  - (closest to Lead, Lead Bandit, LOC)

G69

- To be designated L&S target
  - (L&S, Launch and Steer, ACRONYM)

(G70, G71, CAUSE-OF) - ?

G71

- To change SELF pass to (slightly) left-to-right
    - Pursuer(s): STAG Lead

G70

- To manoeuvre for a forward quarter AIM-120 shot
  - To extend to the west (S-Goal)
    - (in afterburner, HOW) - ??
    - Pursuer(s): STAG Lead

- To direct #3 & #4 G72
    - Pursuer(s): STAG Lead

G72

- To bracket the bandit formation
  - To attack the bandit trailers (S-Goal)
    - (on the beam, LOC)
      - To offset north-east (S-Goal)
        - Pursuer(s): STAG Lead

- To advise [implied: wingmen] G73
    - Pursuer(s): STAG Lead

G73
- To attempt G74

G74
- To engage at LOC5& with WEAP1
  (right forward quarter, both leaders, LOC5)
  (WEAP1, AMRAAM, WEAPONRY)
  (AMRAAM, Advanced Medium Range Air-to-Air Missile, ACRONYM)
- To egress away from #3 and #4 at ALT19
  (round-up, post attack, at the FAOR datum, LOC)
  (ALT19, ANGELS 11, ALTITUDE)
    - (FAOR, Fighter Area of Operational Responsibility, ACRONYM)

- To listen (intently) to G74 &
- To (be able to) confirm radar contact on bandits &
- To advise NE is green, post-attack - ??
    - Pursuer(s): BULMER

- To sort & target trailing bandit element &
- To manoeuvre to G75

G75
- To attack
  (sufficient offset, HOW)
  (bandit's left forward quarter, LOC-FROM)
    - Pursuer(s): STAG #3 & #4

G76
- To launch AMRAAM
  (11 nm from lead bandit element, LOC)
  (first, AMRAAM, RELATIVE-NUMBER)
      (AMRAAM, Advanced Medium Range Air-to-Air Missile, ACRONYM)
  (bandits, TARGET)
    - Pursuer(s): STAG Lead

- To (immediately) command G77
    - Pursuer(s): STAG Lead

G77
- To designate bandit lead element wingman as the L&S target
    - Pursuer(s): radar

**Page 5.19 (57)**

WHILE
- To jink away from bandits
    - Pursuer(s): STAG Lead

- To launch AMRAAM &
  (second, AMRAAM, RELATIVE-NUMBER)
  [implied (bandits, TARGET)]
  (AMRAAM, Advanced Medium Range Air-to-Air Missile, ACRONYM)
- To (immediately) pump &
  (south-west, DIRECTION)
- To deploy multiple bundles of chaff
    - Pursuer(s): STAG Lead

- To egress south-west
    - Pursuer(s): STAG Lead

- To show STAG Lead targeted with semi-active radar missiles in flight
    - Pursuer(s): RWR (STAG Lead)
      (RWR, Radar Warning Receiver, ACRONYM)

(G76, WHEN)
G80
- To advise a trailing bandit hard 'G' spike into his pair
    - Pursuer(s): STAG #4

- To confirm G80
    - Pursuer(s): element lead #3

- To launch AIM-120 &
    - Pursuer(s): #3
  (12 nm from target, LOC-AT)
- To launch AIM-120 &
    - Pursuer(s): #4
  (12 nm from target, LOC-AT)

- To pump south-east &
- To dispense chaff

DURING (egress)
    - Pursuer(s): #3 & #4

- To (be unable to) confirm all bandits splashed
    - Pursuer(s): BULMER

- To go quiet
    - Pursuer(s): RWR (STAG Lead)
        (RWR, Radar Warning Receiver, ACRONYM)

- To be anxious G81

G81

- To regain mutual support with wingmen (OWN)
    - Pursuer(s): STAG Lead

Time (after a few minutes)
WHEN
(just as the 3-ship round-ups at the FAOR datum)

- To advise TAR2 of FACT1 by ME1
  (TAR2, F-3 FAOR, EQUAL)
  (FACT1, a possible bandit leaker entering their FAOR, EQUAL)
  (ME1, common frequency, MEANS)
  (FAOR, Fighter Area of Operational Responsibility, ACRONYM)
    - Pursuer(s): BULMER

- To give TAR3 a snap vector G82
  (TAR3, DART flight, EQUAL)

G82

- To engage the surviving bandit

Time (2025Z)

- To resume counter-rotating CAP
  (FAOR datum, LOC)
      (FAOR, Fighter Area of Operational Responsibility, ACRONYM)

DURING
(next several rotations)

- To maintain radio silence &
- To search for radar contacts

EXCEPTION

- To monitor the R/T
- To monitor the engagement in the adjacent FAOR
  (radar, MEANS)
  (CAP turns, DURING)

Time (23038Z)

- To observe G83
    - Pursuer(s): radar [whose??]

G83
- To transit the FAOR
  ((low levels, LOC1) &
  (on an LLTR, LOC2))
  (4 nm, SEPARATION)
  (360 kts, G/S)
  - (LLTR, Low Level Transit Route, ACRONYM)
  - (G/S, Ground speed (in kts), ACRONYM)
    - Pursuer(s): two [unspecified] elements of aircraft

(G85, G84, CAUSE-OF)

G84
- To (not engage) Pursuer(s)(G83)
    - Pursuer(s): STAG

G85
- To adhere to airspace control measures on the LLTR.
  - (LLTR, Low Level Transit Route, ACRONYM)

Time (later)
- To IFF interrogate Pursuer(s)(G83) as friendly
    - Pursuer(s): STAG

Time (1245Z)
- To deteriorate (somewhat) at ALT20
  (ALT20, ANGELS 11-12, ALTITUDE-RANGE)
  (ALT20, sanctuary altitudes (STAG FAOR), EQUAL)

Time (2048Z)
DURING
  (Stag #3 & #4 hot leg)
SHORTLY-AFTER
  (LINK 16, BENT, STATE-GOES)
- To give a snap vector to pop-up radar contacts approaching the FAOR boundary from the north
    - Pursuer(s): BULMER

- To advise two bogeys, fast and on-the-deck
    - Pursuer(s): BULMER

- To (immediately) commit out of the CAP &
- To accelerate to 500 KCAS &
- To attempt to find clean air
  - To descend (S-Goal)
    (KCAS, Knots Calibrated Airspeed, ACRONYM)
    - Pursuer(s): STAG #3 & #4

- To fall into 5 nm radar trail &
- To offset (slightly) to the east
    - Pursuer(s): STAG Lead

- To attempt G86
- To (occasionally) BUDDY-SPIKE #3
    - Pursuer(s): STAG #4

G86

- To maintain tactical formation integrity
  (deteriorating weather, STATE) &
  (loss of DOLLY, STATE)
  (DOLLY, Descriptive call indicating Data Link equipment, EQUAL)
    - Pursuer(s): STAG #4

- To give a (quick) BRAA report G87
    - Pursuer(s): STAG #3

G87

- To indicate a (slightly) cold intercept
  (left-to-right, POSITION)
  (two targets on-the-deck)
  (.9 IMN, SPEED)
    - (IMN, Indicated Mach Number, ACRONYM)
    - Pursuer(s): STAG #3

    - To (be unable to) interrogate the targets
        - Pursuer(s): STAG #3

    - To call radar tied &
    - To advise G88

G88

    - To (be unable to) acquire the bogeys
        - Pursuer(s): STAG #3

- To turn hard into formation (#3)
  (12 nm, LOC-RANGE)
    - Pursuer(s): radar (STAG #3)

- To (almost immediately) call PINNACLE, PINNACLE &
  (PINNACLE, R/T made by an aircraft to indicate that his RWR shows targeting by an adversary aircraft with probable missile in flight, EQUAL)
  (R/T, Radio Transmission, ACRONYM)
  (RWR, Radar Warning Receiver, ACRONYM)

- To pump G89
  - Pursuer(s): STAG #4

G89

- To egress south-east &
- To deploy multiple bundles of chaff
  - Pursuer(s): STAG #4

- To designate one of the bogeys &
- To launch AMRAAM &
  (last, AMRAAM, RELATIVE-NUMBER)
  - (AMRAAM, Advanced Medium Range Air-to-Air Missile, ACRONYM)
- To egress south-east &
- To call a HEADS-UP, LEAKER
  (Stag Lead, CALL-TO)
  - (HEADS-UP, Descriptive call indicating a short range GCI contact or that the fighter has lost contact with the bogey/bandit (usually at the merge)
    (GCI, Ground Controlled Intercept, ACRONYM)
  - (LEAKER, Descriptive call indicating a targeted entity has survived a merge/intercept and still poses a threat)
    - Pursuer(s): STAG #4

- To advise contact, sorted and clean and elects G90
  - Pursuer(s): STAG Lead

G90

- To engage the leaker
  - Pursuer(s): STAG Lead

- To observe G91
  (10 nm, LOC (STAG Lead))

G91

- To disappear off scope (STAG Lead)
  - Pursuer(s): one radar contact
- To (immediately) locks &
- To shoot an AIM-7M
  (remaining bandit, TARGET)
  - Pursuer(s): STAG Lead
- To F-Pole &
  (north-east, DIRECTION)
- To expend chaff &
- To descend to ALT40
  (ALT40, area safe altitude, ALTITUDE)
  - Pursuer(s): STAG Lead

Time (TTG zero)
  (TTG, Time-To-Go, ACRONYM)

- To reverse back &
  (CAP datum, LOC) - ??
- To call for round up & formation STATUS
  (STATUS, R/T request for an individual's tactical situation/position, EQUAL)
  (R/T, Radio Transmission, ACRONYM)
    - Pursuer(s): STAG Lead

- To advise G92
    - Pursuer(s): BULMER

G92

- To splash
    - Pursuer(s): both bogeys

- To round up
  (FAOR datum, LOC)
  (2053Z, TIME)
    - Pursuer(s): STAG

CA1

- To call S100
  (S100, established in the counter-rotating CAP &
- To declare 15 minutes PLAYTIME
    - (PLAYTIME, Descriptive call indicating amount of available on-station time; expressed in minutes, EQUAL)
        - Pursuer(s): STAG Lead

- To acknowledge [implied: CA1] &
- To advise getting RTB for VICTOR
  (RTB, Return-To-Base, ACRONYM)
  (VICTOR, the tasked diversion base, EQUAL)
    - Pursuer(s): BULMER

**Page 5.20 (58)**

### 5.4.11 Recovery to Operating Base

Time (2105Z)
CL20

- To issue clearance for G100 &
- To advise getting RTB for VICTOR
  (RTB, Return-To-Base, ACRONYM)
  (VICTOR, the tasked diversion base, EQUAL)

    - Pursuer(s): BULMER

G100
- To depart the FAOR &
- To effect direct routing to the recovery aerodrome outer approach beacon
- To descend to ALT70 &
  (ALT70, ANGELS 6, ALTITUDE)
- To contact surveillance radar (VICTOR)
  (TAD 26, MEANS)
    (TAD, Tactical Air Designator (Radio Frequency, ACRONYM)
    - Pursuer(s): STAG

- To acknowledge CL20
    - Pursuer(s): STAG Lead

- To request FACTS40 &
  (FACTS40, (Final) Fuel & (Final) Ammo States)
- To direct #3 & #4 G101

G101
- To assume 3 nm radar trail
    - Pursuer(s): STAG #3 & #4

(tied with #4 in close formation, #3, STATE)
- To descend &
- To route directly to outer marker (VICTOR)
  (EGI, MEANS)
  ((MMD, MEANS)
    (EGI, Embedded Global Positioning/Inertial Navigation System, ACRONYM)
    (MMD, Moving Map Display, ACRONYM)
    - Pursuer(s): STAG Lead

(Check-in, STAG Lead, VICTOR, STATE)
- To request G102
    - Pursuer(s): VICTOR

G102
- To authenticate &
- To change IFF codes &
- To squawk IDENT
    - Pursuer(s): STAG Lead

N20 (Notification #20)
- To advise FACTS50
    - Pursuer(s): VICTOR

F50 (FACTS #50)
    (IN-EFFECT, SHORAD approach procedures to runway 11, STATE)
        (SHORAD, SHOrt Range Air Defence, ACRONYM)
    (OUT, Navigation approach aids, STATE)
    (PROVIDED, flight traffic advisory to commencement of the SHORAD approach only, STATE)
    (29.74, Airfield Altimeter, EQUAL)
    (1 nm, surface visibility, EQUAL)
    (300 feet AGL, ceiling, EQUAL)

Time (at N20)

- To request F51
    - Pursuer(s): STAG Lead

F51 (FACTS #51)
(<ST10>, pre-planned mission diversion base, STATUS)
    (ST10, STATUS #10, EQUAL)

- To inform STAG Lead F52
    - Pursuer(s): VICTOR - ??

F52 (FACTS #52)
(not usable, pre-planned mission diversion base, STATUS)

(F53, F52, CAUSE-OF)

F53
([unspecified Other] & Not cloud OR visibility minima, STATES)

- To direct STAG G G103
    - Pursuer(s): VICTOR - ??

G103

- To land at Victor
    - Pursuer(s): STAG

Time (Midway during transit to join the SHORAD approach at VICTOR)

- To acquire radar contact on a base defence CAP
    (base defence, (established to the - ??) north of Victor Aerodrome, LOC)

RQ20 (Request #20)

- To request G104
    - Pursuer(s): STAG Lead

(G105, G104, REASON-FOR)

G104
- To deviate [implied: from established routing]
    - Pursuer(s): STAG

G105
- To avoid the CAP
    - Pursuer(s): STAG

- To direct STAG Lead G106
    - Pursuer(s): VICTOR - ??

G106
- To set heading 225° &
- To expedite descent to 2,000 feet MSL
    - Pursuer(s): STAG Lead

DURING
- To pass the CAP
    - Pursuer(s): STAG

- To buddy-spike STAG
    - Pursuer(s): ??

WHEN

(Clear of the CAP, STAG, STATE)
- To clear own navigation G107
    - Pursuer(s): VICTOR - ??

G107
- To complete the SHORAD approach
    - Pursuer(s): STAG

G108
- To join the runway centerline at 45°
    - To offset OWN radar trail formation (S-Goal)

    (15 nm back, LOC)

(G108, conforms to SHORAD approach procedure, STATE)

- To establish [this] intercept &
- To slow to 300 KCAS &

G108c
- To switch the 3-ship over to GAMBIT operations

(G108c, to give status reports, PURPOSE-OF) - ?? who will give to whom? - ??

- To inform STAG F54
    - Pursuer(s): VICTOR - ??

F54
(6,000 feet, MOS, STATE)
    (MOS, runway 4-bar, COMMENCING)
    (MOS, high-speed cut-off, EXTENDING-TO)
        (MOS, Minimum Operating Strip, ACRONYM)

DURING
(45° base leg to join the centerline
    (15 nm back, SAG, LOC)

- To radar designate the runway centerline with AT1
    - Pursuer(s): STAG Lead & #3

AT1 (Attribute(s) #1)
        (adjacent the eighth runway light down from the approach end, LOC)
        (corresponding the approximate 4-bar position, LOC)

- To select Expand 3 DBS radar mode
  (DBS, Doppler Beam Sharpening, ACRONYM)
    - Pursuer(s): STAG Lead & #3

AS
(radar builds on designation, STATE)

- To sweeten the intended touchdown point/designation
    - Pursuer(s): STAG Lead & #3

- To corroborate the designation
    - Pursuer(s): EGI & MMD
      (EGI, Embedded Global Positioning/Inertial Navigation System, ACRONYM)
      (MMD, Moving Map Display, ACRONYM)

- To join the runway centerline &
- To slow the (radar trail) formation
  (15 nm back, LOC- RELATIVE)
  (250 KCAS, SPEED)
  (1500 feet, AGL)
    - Pursuer(s): STAG Lead

TIME-RELATIVE (at this point)

- To fly independent, radar-designated, SHORAD approaches to short final and landing
    - Pursuer(s): STAG Lead & #3

WITH

- To fly in close formation
    - Pursuer(s): #4

TIME-RELATIVE (7 nm back)
- To extend landing gear & land flap &
- To set radar altimeter to 150 feet AGL &
- To fly a 2 1/2° glidepath to their point of radar designation.

(200 feet, AGL)
- To break out of cloud &
- To execute uneventful full-stop landing
    - Pursuer(s): CF-18s

Time (2115Z)

- To taxi in for de-arming
    - Pursuer(s): CF-18s

- To shut down
  (designated parking, LOC) &
  (assigned HASs, LOC)
    - Pursuer(s): CF-18s

TIME-RELATIVE (post shutdown)
- To debrief the recovery & turn-around crews &
- To proceed to operations area for G109
    - Pursuer(s): CF-18s

G109
- To sign-in aircraft &
- To engage in full mission debrief
    - Pursuer(s): CF-18s

- To determine composite mission scenario tasking is concluded &
- To conclude mission is an over-all success
    - Pursuer(s): ??

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14. ABSTRACT

The purpose of this contract was to extend earlier work on goal-tracking interface design principles and methods in order to support adaptive aiding for the CF-18 air domain. A systematic methodology for analysing, designing and building an intelligent help system made use of the CommonKADS knowledge management and engineering methodology, the Explicit Models Design methodology, used in the earlier work, and concepts from the Software Agent Paradigm. Much of the work involved developing templates for representing knowledge contained in a Composite Mission Scenario (CMS) and using those to represent its content. A proposal for managing and engineering help for the CF-18 domain was proposed. Given the development stage of DRDC Toronto's CF-18 simulation, it was not possible to incorporate the work this work into the simulation, however, other alternatives were examined, the most viable of which involved adapting a commercial, off-the-shelf product. Recommendations for future work included refining and extending the proposed methodology, the templates for representing knowledge in the air domain, and concluding that will permit adapting a commercial off-the-shelf simulation to demonstrate intelligent aiding. The last item will help inform the best approach to implementing intelligent aiding for the DRDC simulation, as work on that nears completion.

RÉSUMÉ

[to be done]

15. KEYWORDS, DESCRIPTORS OR IDENTIFIERS

(U) CF-18; COGNTIVE COCKPIT; COMMONKADS; EXPLICIT MODELS DESIGN; INTELLIGENT AIDING; INTELLIGENT AND ADAPTIVE INTERFACES; INTELLIGENT HELP; INTELLIGENT INTERFACE DESIGN; KNOWLEDGE ENGINEERING; KNOWLEDGE MANAGEMENT; KNOWLEDGE REPRESENTATION; PLAN RECOGNITION; PLAN GENERATION; SIMULATION; WORLD MODEL.